Groundfish Stock Assessments for the West Coast of Canada in 1984 and Recommended Yield Options for 1985

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GROUNDFISH STOCK ASSESSMENTS FOR THE WEST COAST OF CANADA IN 1984 AND RECOMMENDED YIELD OPTIONS FOR 1985

by

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Editors

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ABSTRACT

Tyler, A. V. and G. A. McFarlane (Eds.). 1985. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 353 p.

Stock assessments and yield options are developed for the Pacific coast of Canada for the following species: lingcod, Pacific cod, Dover sole, rock sole, English sole, sablefish, Pacific hake, spiny dogfish, walleye pollock, Pacific ocean perch, yellowmouth rockfish, rougheye rockfish, silvergrey rockfish, yellowmouth rockfish, and canary rockfish. The yield options are recommendations to the fishery managers of the Field Services Division on catch limitations and other fishery management procedures. Biological considerations only, rather than economic factors, are addressed in this document. The yield options are quantitative and are based on a series of appropriate mathematical methods, e.g., virtual population analysis, dynamics pool analysis, and Fournier stock-reconstruction procedures. Alternative options address the possibility of the fishery managers considering high risk and low risk yields in relation to a stock's future potential to produce. Other options, particularly for rockfish and flatfish species, provide a selection of alternatives for managers to consider in regard to whether a stock should be re-built, maintained at status quo, or decreased through non-sustainable catches for present economic emergencies.

Key words: groundfish, stock assessment, fishery yields

RESUME

Tyler, A. V. and G. A. McFarlane (Eds.). 1985. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 353 p.

Les auteurs présentent des évaluations de stocks et des possibilités de rendement pour des espèces du Pacifique: la morue-lingue, la morue du Pacifique, la sole, la sole du Pacifique, la sole anglaise, la morue charbonnière, le merlu du Pacifique, l'aiguillat commun, la morue du Pacifique occidental, le sébaste à longue mâchoire, le sébaste à bouche jaune, le sébaste à oeil épineux, le sébaste argenté, le sébaste à queue jaune et le sébaste canari. Les possibilités de rendement représentant des recommandations relatives aux limites de capture et à d'autres méthodes de gestion halieutique à l'intention des gestionnaires des pêches de la Division des services extérieurs. Le présent document porte seulement sur les facteurs biologiques et non écnomiques. Les possibilités de rendement sont de nature quantitative et basées sur une série de méthodes mathématiques qppropriées, c.-à-d. l'analyse de population virtuelle, l'analyse dynamique de groupes et les techniques de Fournier pour la reconstitution d'un stock. Les diverses possibilités se situent au niveau de l'examen des rendements à risque élevé ou faible par rapport au potentiel de production future d'un stock. D'autres possibilités, surtout pour les sébastes et les poissons plats, sont offertes au gestionnaire pour lui permettre de faire un choix éclairé entre le rétablissement d'un stock, son maintien au statu quo ou son déclin par l'entremise de captures à un taux de recrutement non soutenu à cause des facteurs économiques pressants actuels.

Mots-clés: poissons démersaux, évaluation de stock, rendements des pêches

1.0. INTRODUCTION

This report was prepared by the staff of the Groundfish Section of the Fisheries Research Branch of the Canada Department of Fisheries and Oceans, located at the Pacific Biological Station, Nanaimo, British Columbia, Canada V9R 5K6. This report contains biological assessments of the important groundfish stocks, and recommendations for their management to the Offshore Division of the Field Services Branch of the same Department.

Biological stock assessments vary in mathematical sophistication depending upon the underlying data available. Resulting recommendations are expressed here as a series of yield options. Yield options are in turn converted by fishery managers to regulations that may take the form of catch quotas, landing or trip limits, area closures, or any combination thereof. When a yield option is expressed as a tonnage limit on total annual catch, the corresponding regulation expressing the annual limit is termed a catch quota. A yield option may be expressed as a trip limit--the total weight that may be landed as a result of one vessel-trip. It is recognized that trip limits are a problematic means of limiting the annual catch from a stock to a selected total tonnage level, but in a traditional fishery a trip limit may be preferable to a landings quota because a trip limit can spread the catch over a period of time. Sometimes a trip limit will be combined with a landings quota as a dual control approach. If the accumulated landings of a species during the year exceeds the calculated sustainable level despite a trip limit being in effect, the area of concern might be closed to further fishing.

For most stocks, two or more alternative yield options are given as recommendations arising from the stock assessment analyses. Some of the yield options are related to the level of risk that the manager might wish to take. There is more than one level of risk because potential-catch estimates are characterized by a degree of uncertainty. Calculations made by fishery biologists can be carried through at either a conservative level, or at a high-risk level. High risk means that there is a good chance that potential yield in future years will be sacrificed if this catch level is selected. However, sometimes the high risk is warranted when severe and special economic circumstances occur in a particular year.

We sometimes have the choice of whether to re-build a stock, or to sustain a stock at its present low level, or finally, to recommend the removal of a catch that is unsustainable and that will most certainly interfere with the capability of the stock to produce in the future. The unsustainable yield option would be selected only under conditions of extreme economic duress. Sustainable levels that are substantially lower than the maximum potential yield from the stock are also advisable only when temporary socio-economic conditions prevent the selection of a re-building strategy that will eventually allow a stock to regain its full production potential.

In this report we have used the terms Landings and Landings per Unit Effort (LPUE). This is because at-sea discard rates are not known on an annual basis. Discards must be added to landings to calculate the catch. Fishery management areas referred to in this report are given in Fig. 1.1 and Fig. 1.2. When we refer to statistical Area 3C that straddles the Canada-United States border, we consider only the Canadian portion.

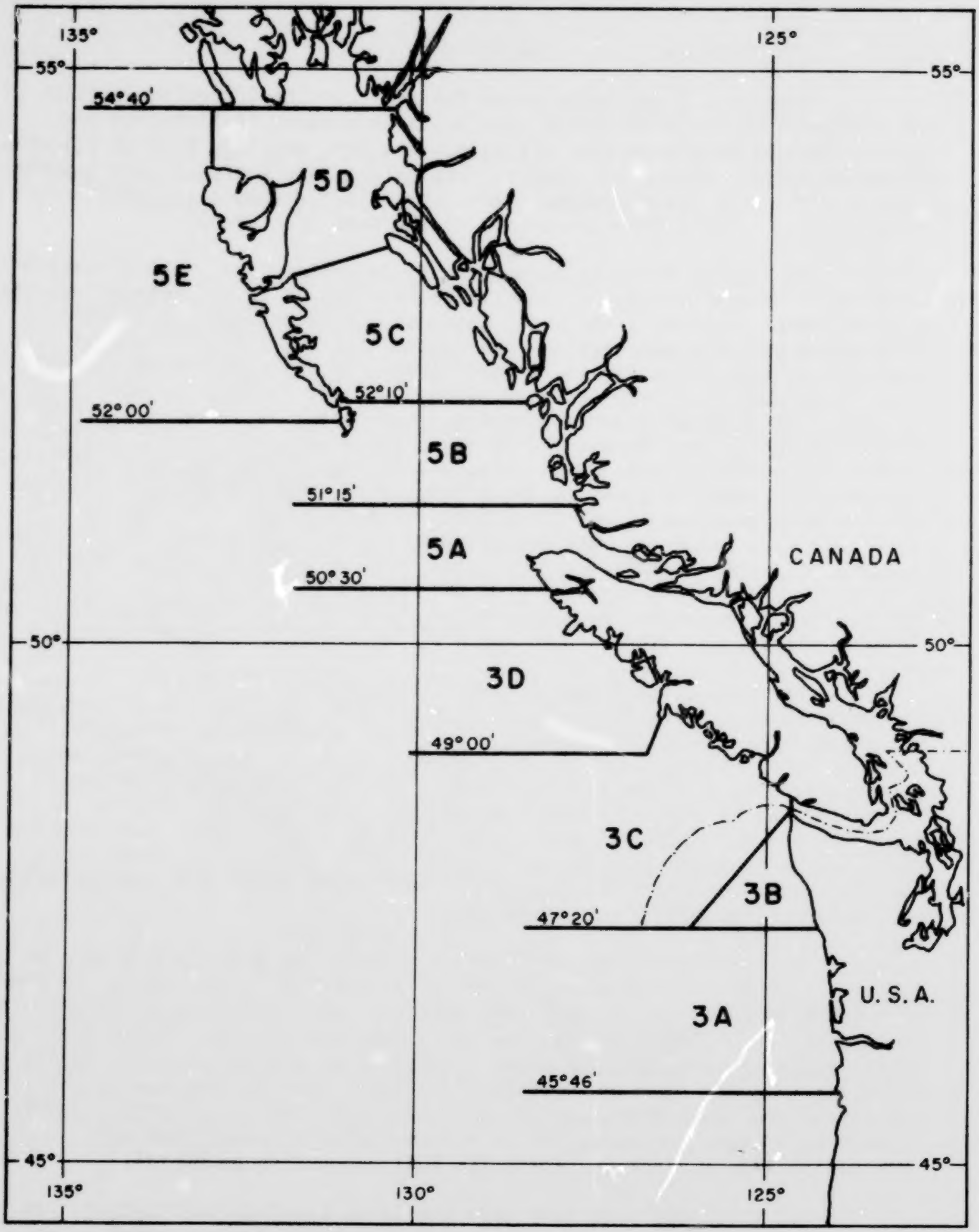
135°
125°
55°
55°
54°40'
5D
5E
5C
52°10'
52°00'
5B
51°15'
5A
CANADA
50°30'
50°
50°
3D
49°00'
3C
3B
47°20'
U.S.A.
3A
45°46'
45°
45°
135°
130°
125°

Fig. 1.1. International (Pacific Marine Fisheries Commission) Major Statistical Areas along the British Columbia coast.

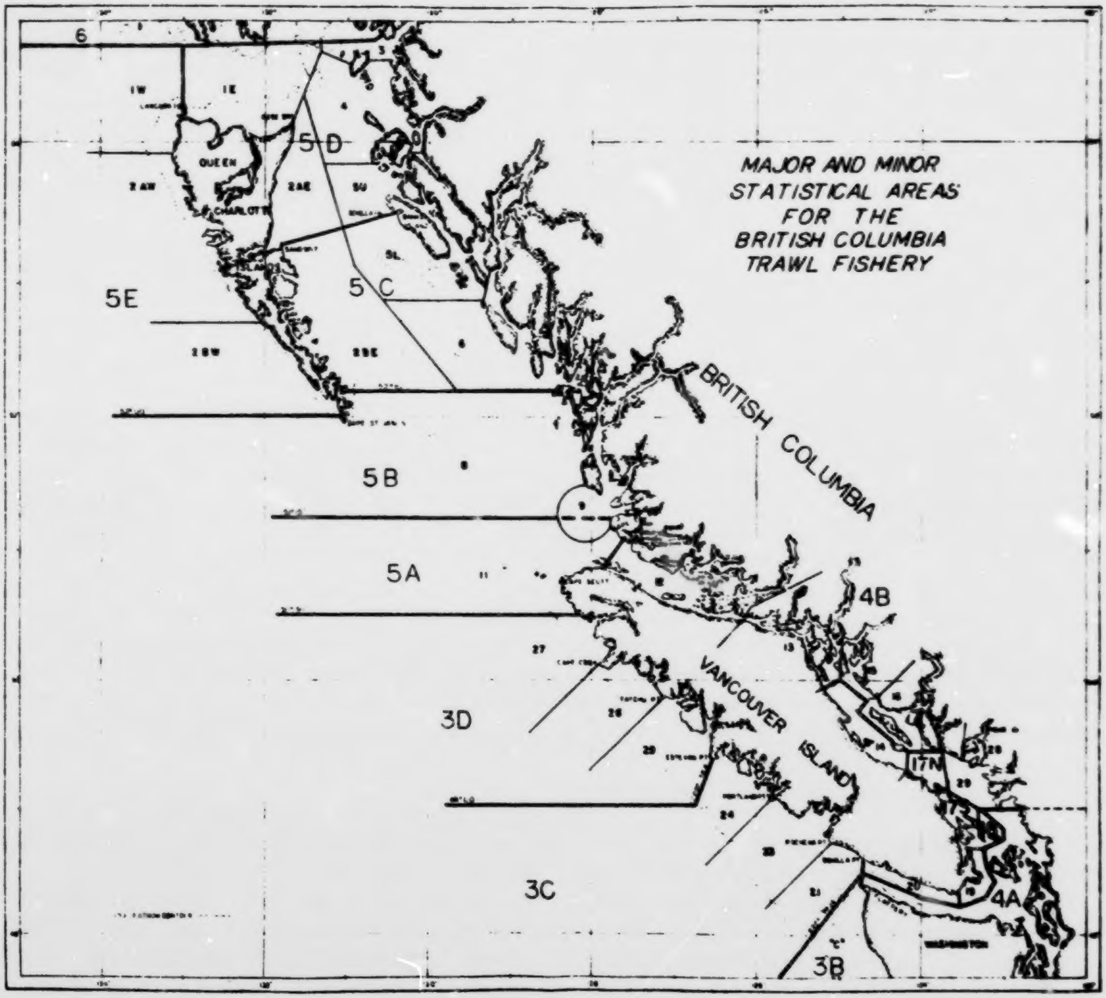
MAJOR AND MINOR
STATISTICAL AREAS
FOR THE
BRITISH COLUMBIA
TRAWL FISHERY
6
1W
1E
QUEEN
CHARLOTTE
2AW
2AE
5D
5E
5C
2BW
2BE
5B
5A
3D
3C
3B
4B
4A
17N
BRITISH COLUMBIA
VANCOUVER ISLAND
WASHINGTON

Fig. 1.2. International (Pacific Marine Fisheries Commission) Major and Minor Statistical Areas along the British Columbia coast.

EXECUTIVE SUMMARY OF RECOMMENDATIONS FOR 1985

This summary of recommendations to the Field Services Branch of the Canada Department of Fisheries and Oceans (D.F.O. Pacific) was prepared by the staff of the Groundfish Section of the Fisheries Research Branch (D.F.O. Pacific) as biological management advice for consideration by the designated fisheries managers. A full explanation of the quantitative analyses and data is given in the accompanying report.

Recommendations for selected species and species groups are presented by Management Region and Area as a summary text and tables. Tables 1 and 2 are listings of rockfish yield options. Table 3 is a listing of all other yield options.

1. Region: Coastwide

Recommendations for sablefish

It is recommended that the yield option for sablefish be increased in a "stepwise" fashion over the next few years in order to take advantage of the increase in exploitable biomass. A conservative approach to increasing recommended yield is proposed. Continued close monitoring of the fishery is essential in order to assess this strategy.

The recommended yield option at the conservative level for 1985 is 4,000 t. It is anticipated that the recommended yield will remain at 4,000 t through 1986, at which time more recent age composition data will be available for further age-structured analysis. An alternative suggested yield option at a high risk level could be as much as 5000 t in 1985. There is a possibility that this risk level option will interfere with future yield for the fishery.

Recommendations for dogfish

A sustained fishery will also produce oscillations in abundance but they will decrease in size with time. Hence a constant catch strategy provides a steady supply while maintaining a stock size considerably lower than present nuisance levels. Levels of yield up to 15,000 t may be considered low risk and from 15,000-25,000 t high risk with respect to sustainability based on ranges of compensatory mortality and starting stock size. It is recommended that a low risk sustained yield be adopted.

2. Region: Strait of Georgia

Recommendations for lingcod

Sufficient time has not elapsed to evaluate the impact of the extended winter fishing closure on recruitment. Therefore we recommend that the present lingcod closure be continued in 1985.

We further recommend a minimum size limit for sports line-caught lingcod, similar to the size limit for the commercial fishery (58 cm). The purpose of this recommendation is to reduce the removal of immature lingcod. This may be particularly relevant in MSA 13 where declining levels of sport catches and handline LPUE in recent years warrant additional concern for stocks in that area. Small lingcod appear to reside in shallower water than larger fish and, while the practice of persistent fishing and discarding under-sized fish until a "keeper" is caught will dampen the benefits of a size limit, sports effort could on its own be re-directed to areas populated by larger lingcod due to the regulation, thereby directly reducing the catch of immature lingcod without a high discard rate.

Recommendations for Pacific hake.

A yield option with yields not exceeding 10,000 t is recommended. As catches begin to approach this level, monitoring of the fishery will allow us to re-assess our estimates. A yield option at a high risk level could be as high as 15,000 t, however the reproductive response of the stock to exploitation must be carefully monitored.

Recommendations for dogfish

Dogfish may be harvested on a sustained or periodic fishery basis. Periodic fisheries produce and perpetuate oscillations in abundance and should be evaluated with regard to their impact on the stock at the time of their proposal. Sustained fisheries provide the most stable harvest strategy.

The trends in inshore abundance presented can be viewed only qualitatively until questions regarding the degree of mixing between Puget Sound and Strait of Georgia stocks and the impact of sports fisheries have been answered and until a reliable estimate of absolute abundance is obtained for accurate calibration of model projections. It is recommended that a low risk option of 3,000 t be maintained for the Strait of Georgia (4B).

Recommendations for walleye pollock

Yield options range from a conservative 2,350 t to a high risk 10,500 t. Based on our understanding of the biology of pollock (a=0.4; m=0.5-0.6) and a mid-point in the biomass estimate (22,600 t) we recommend that a yield option be chosen between 2,500 t and 5,400 t.

3. Region: West Coast of Vancouver Island

Recommendations for lingcod

Delay-difference modelling indicates yields are sustainable at exploitation rates of 0.5. Evidence from tagging studies (Cass et al. 1983b) indicates exploitation rates in 1982 were 0.34. These results indicate stocks off the west coast of Vancouver Island are currently under-exploited.

In this analysis we have attempted to present extreme ranges of yield options that reflect some uncertainty in our estimate of natural mortality. A conservative estimate of MSY for Area 3C is about 900 t/yr and

450 t/yr for Area 3D. Upper ranges for these areas are 1404 t/yr and 507 t/yr, respectively.

It is unlikely, given current market limitations, that exploitation rates can be increased. We therefore are not making any recommendations to alter harvesting strategies off the west coast of Vancouver Island.

Conclusions and Recommendations for Pacific cod

Available evidence strongly suggests that the cod stock in Area 3C is at an extremely low level of abundance. Therefore, a very conservative management philosophy should prevail.

Three alternative actions are proposed--conservative, intermediate, and optimistic. The conservative proposal is to close Area 3C to trawling at ≤ 100 fath, during January-March, assuming that recruitment overfishing is imminent or has already occurred. The intermediate proposal is to allow one week of trawling in the middle of January, February, and March in Area 3C at ≤ 100 fath, assuming recruitment overfishing is not quite so imminent. The optimistic proposal is to apply no regulations, assuming that recruitment overfishing is not likely.

Recommendations for Petrale sole

In 1967, after results of a study of petrale sole population dynamics were published (Ketchen and Forrester, 1966), the TSC (Canada-U.S. Groundfish Committee) recommended abolishing regulations for petrale sole stocks on the Pacific coast (in place since 1958).

A 40,000 lb. trip limit is currently in effect for petrale sole in Areas 3C and 3D from January-March. This regulation is the result of a request by industry, and could be continued.

Recommendations for walleye pollock

An unlimited yield option is proposed for this region. Accurate estimates of incidental catch and biomass are unavailable. In addition, the extent of interchange between this stock(s) and pollock in the Strait of Georgia is currently being investigated. When these studies are completed, coupled with the accumulation of more accurate catch/effort statistics from Areas 3C and 3D, the stock will be re-evaluated.

Area: 3C. Lower West Coast of Vancouver Island

Recommendations for Pacific hake

The stock assessment indicates a high risk yield option of 67,000 tonnes in 1985. Due to the uncertainties in the hydroacoustic estimates a conservative yield option of 45,000 tonnes is preferred.

Recommendations for Pacific ocean perch

The long-term effects of the major fishery of the 1960s are difficult to predict. This difficulty arises due to the apparently widespread nature of intermittent strong year-classes of S. alutus in the northeast Pacific, the lack of an adequate time series of catch-at-age data, and the problems of perceiving the stock-recruit relationship for this and most other rockfish stocks. In spite of this, the evident lack of strong cohorts generated after the major fishery of the mid-1960s coupled with lowered stock biomass and a truncated age spectrum cannot be ignored.

For the past three years we have recommended an experimental, controlled overharvest of the southern stock to produce a negative pulse in the age composition of the stock and which could be useful to validate both biomass and age estimates. For 1985, we therefore recommend that the harvest strategy for this stock be returned to the sustainable or conservative level (Table 9.2.1.4); conservative sustainable and non-sustainable yield options are non-directed fishing, 300 t and 500 t, respectively. The sustainable level is based on an F = M policy applied to the 6200 t biomass estimate for the Canadian zone. A joint Canada-U.S. biomass survey of the southern S. alutus stock is planned for 1985. The results of that survey and analysis of the age composition data for the stock will be used to evaluate existing biomass estimates and the experimental overharvest.

The foregoing assumes yield removed in the Canadian zone is entirely supported by the proportion of the stock in the Canadian zone, rather than being supported by the stock as a whole. This tenet is unproven and a more desirable course would be to manage the 'stock' jointly with the U.S. It is particularly important to reach an accord with the U.S. concerning the appropriate level of exploitation for this and other rockfish stocks. In the case of the S. alutus stocks, the recommended TAC in U.S. waters is 600 t (Tagart and Leaman 1982), a figure which we view as a non-sustainable yield. If the fish within the two zones do constitute a single stock, then any Canadian attempts to achieve rehabilitation will be fruitless in the absence of matching policies in the U.S. zone.

Recommendations for silvergrey rockfish

The conservative, sustainable and non-sustainable yield options are virtually unchanged from 1984. The conservative, equilibrium, and non-equilibrium options are: a non-directed fishery; 100 t; and 200 t. We recommend that S. brevispinis be included as part of a combined shelf rockfish yield (see Section 9.3.3.4.).

Recommendations for yellowtail rockfish

The limited production from Canadian 3C over the last 18 years strongly suggests that very little of the stock has been available to Canadian trawlers and that the current incidental landings in the hake fishery may be removing close to the sustainable yield from this population if it is immobile within Area 3C. A highly conservative yield option would then imply that the domestic fishery be of a non-directed nature.

If yields from this fishery become significant, they must be considered in conjunction with U.S. removals. U.S. biologists have assumed S. flavidus to be a unit stock for all of the Vancouver area and suggest a maximum sustainable yield of between 1500 and 2000 t (Tagart 1982) although this may be revised downwards as they incorporate break-and-burn ageing techniques.

If a highly conservative option is not chosen, then it is recommended that discussions be initiated with U.S. authorities about joint management of this stock. In the interim, a directed yield of 200 t might be considered. This yield plus 300 t from the hake fishery far exceeds the traditional Canadian landings from this area without exceeding 33% of the current U.S. perception of the stock's MSY.

Recommendations for canary rockfish

This stock, if immobile, cannot sustain a directed fishery, so the conservative yield option would be that of a non-directed fishery. Similarly with S. flavidus, a quota for a directed fishery cannot be considered apart from U.S. management so negotiations should be begun regarding joint management. In the interim, it is recommended that a ceiling quota of 200 t be applied to the domestic fishery. A grouped species option is discussed in Section 9.3.3.4.

Area: 3D. Upper West Coast of Vancouver Island

Recommendations for Pacific ocean perch

No new information pertaining to stock assessment is available. The recommended yield options under harvest strategies (Table 1) reflect historical landings rather than any stock analysis. The conservative, sustainable and non-sustainable yield options are 250 t, 350 t, and 500 t, respectively.

Recommendations for silvergrey rockfish

Conservative, equilibrium, and non-sustainable yield options are raised slightly from 1984 levels to 150, 350, and 700 t. The equilibrium level is based on the assumption that the fishery is capable of sustaining a harvest level at least equal to the average over the last 17 years given that there is no evidence to suggest the stock is declining. The 1985 options are slightly higher because the 1984 catch was sufficient to raise the historcial mean yield. The non-sustainable level is set at twice the equilibrium yield. S. brevispinis is slow-growing and does not reach full recruitment until at least 20 years of age, so it is presumably vulnerable to exploitation. LPUE and length composition information will be monitored closely and should the stock show symptoms of heavy exploitation, the quota recommendations will be lowered. A shelf rockfish grouped quota and multiple 3D quotas are discussed in Section 9.3.3.8.

Recommendations for yellowtail rockfish

Including the Polish landings generates a mean yield of 600 t over the last 17 years. However, given the marked decline in the second year of that fishery and the relative scarcity based on low domestic yields, the equilibrium yield is probably well below the 600 t level. Guideline yields for conservative, equilibrium and non-sustainable options are unchanged to non-directed, 100 t, and 250 t. Given the incidental nature of this fishery, we recommend that the S. flavidus quota be included as part of the broader rockfish assemblage quota. While the suggested equilibrium yield is 100 t, the low S. flavidus catches in recent years suggest that a combined rockfish quota should assume an S. flavidus contribution of 50 t.

Recommendations for canary rockfish

We continue to assume that the fishery can sustain the average yield that it has produced in the past. S. pinniger conservative, equilibrium, and non-sustainable yield options for 1984 are raised slightly to 250; 500; and 750 t.

Recommendations for a Group Quota (silvergrey, yellowtail, canary)

If it is suggested, that Area 3D be divided again into north and south quotas, consideration should be given to allocating more than 50% to the southern section. In the last 2 years, a greater proportion of the S. brevispinus landings has come from this area and this would assist in keeping the S. brevispinis/S. pinniger ratio closer to 1:40.

The history of U.S. landings suggests that the southern and central portions of Area 3D were exploited more heavily. This is supported by the length composition of S. brevispinis samples but not by those of S. pinniger. We do not recommend managing the two areas separately as we assume that they represent a common recruitment pool.

Suggested combined quotas for the S. brevispinis, S. flavidus, and S. pinniger complex are raised slightly to 250; 750; and 1500 t. Should the species split be close to optional, the overall quota could be raised to match the sum of the individual species options.

4. Queen Charlotte Sound

Recommendations for lingcod

Stocks in Queen Charlotte Sound are currently at high levels. The present analysis suggests recruitment is dependent on environmental factors rather than stock size. At present there is no evidence to indicate the dynamics of lingcod stocks in Queen Charlotte Sound are adversely influenced by fishing pressure. Therefore we are not making any recommendation for Queen Charlotte Island stocks.

Recommendations for Pacific cod

Although exploitation rate has steadily increased during 1961-78, estimated F is low with respect to Z. Furthermore, since 1976, effort (and probably F) has declined substantially. Coupled with the results of the 1982-83 echo-sounder surveys, we can only conclude that the cod stock(s) in Queen Charlotte Sound appear to be undergoing another downward fluctuation in abundance not caused by the fishery.

An important caveat, however, is that the age compositions were calculated from length frequencies summed over quarter-years. Scheduled recalculations from length frequencies summed over months may produce somewhat less favourable results.

No regulations are recommended.

Recommendations for rock sole

Landing statistics in Area 5A suggest that this population has sustained effort levels well above the current level with little change in LPUE. Effort level in 1976 was 60% higher than current levels. It is suspected that landings for rock sole in 5A reflect fluctuations in recruitment, but until age composition data is available this cannot be confirmed.

An upper limit of 500 t is suggested for Area 5A as this is the highest historical yield for the fishery, but regulation is probably unnecessary at present.

Without ageing data or information of species interactions in Area 5B it is difficult to assess the impact of fishing on the stock or the significance of recruitment fluctuations and changes in availability in regard to the catch/effort statistics. At present it is unclear whether the change in abundance as indicated by LPUE from 1973 is fishery induced.

In recent years (1973-1983), excluding the year of 1980 because of unusually high availability, an average sustainable yield of 250 t has been calculated, but regulation is probably unnecessary at present.

Recommendations for Pacific ocean perch

While there is some variance in the estimates of present stock size for *S. alutus* in QCSd, there is a broad consensus that it has been substantially reduced from historic levels and that rehabilitation is necessary. All of the treatments we reviewed have inherent limitations and we have adopted the analysis presented in Archibald et al. (1983) as that most accurately depicting past events as well as providing best guidance for rehabilitation. Support for this evaluation is also derived from Kimura et al. (1984) who described the underlying basis for the analysis as, "...the most comprehensive likelihood approach to stock assessment that exists today."

Rehabilitation strategies outlined in previous assessments remain unchanged. However, the lack of adherence to the catch quotas necessary for rehabilitation in the 1982-84 period compromises achievement of this goal. It is highly probable that the stock biomass has been further reduced since the adoption of this strategy. Table 1 provides yield options which reflect this decrease in biomass and the probable effects on stock rebuilding.

The yields associated with the conservative, sustainable and non-sustainable options are 850 t, 1050 t and 1300 t, respectively. These projected yields are lower than previous values (Stocker 1981) by approximately 15% and reflect the estimated decline of the GIG stock and a re-assessment of the contribution of the MG stock to total yield. If the conservative yield options were to be adopted over a 30 yr period, then stock size would be projected to increase by approximately 50% over this period. A more detailed discussion of possible rehabilitation strategies for this stock is presented in Archibald et al. (1983).

Recommendations for yellowmouth rockfish

Only a single biomass estimate (hydroacoustic) for this stock is available. During October 1978 a biomass of 2000 t was estimated for this stock off Triangle Island. This estimate is believed to be conservative due to the difficulty of accurately estimating the near-bottom component of the stock with hydroacoustic equipment, however the magnitude of this underestimate is unknown. The yield options of Table 1 therefore treat the 2000 t as a minimum biomass estimate and the yield from it (200 t) as a conservative figure. The incremental changes to sustainable (350 t) and non-sustainable (500 t) yields reflect the magnitude of such proportional increments for other stocks, where analyses are more detailed, and our uncertainty in estimating biomass of this stock. We do not believe this stock to be as overexploited as the GIG *S. alutus* stock, however there is evidence of longer exploitation than either the MOR *S. alutus* or the west Queen Charlottes *S. reedi* stocks. We therefore assume the sustainable yield from this stock should be at least 150% of our conservative yield estimate. Additional survey work might decrease the uncertainty of these estimates.

Recommendations for silvergrey rockfish

In the absence of any indication that historical landings have significantly reduced the *S. brevispinis* stock in 5A and 5B, we assume that the sustainable yield is at least equal to the historical mean landings. An equilibrium quota of 750 t is suggested for 1985. Should mean size or LPUE continue to decline, quota recommendations will be lowered in the future. Proposed quota options are 400 t for the conservative option; 750 t for the equilibrium option; and 1200 t for the non-sustainable option. A grouped rockfish option is recommended and discussed in Section 9.3.4.4.

Recommendations for yellowtail rockfish

Quota options are unchanged from 1984 at 500 t for a conservative yield; 1500 t for the equilibrium yield; and 2500 t for the non-sustainable yield. The 1983 sample of relatively small fish is a source of some concern but in itself not important enough to alter our perceptions of the stock's status. Owing to the size of the quota and the likelihood of its not being reached, we recommend that the *S. flavidus* yield be separate from other rockfish.

Recommendations for canary rockfish

In the absence of definite signs of overfishing it is assumed that *S. pinniger* in Areas 5A and 5B can sustain a yield equal to the 17-year average landings. However, should qualified LPUE continue to decline and/or the average age of females decrease further, it would be assumed that current yield should be decreased.

Recommended quota options for 1985 are unchanged at a conservative yield of 200 t; and equilibrium yield of 500 t; and a non-sustainable yield of 1000 t. An option for grouping the quota with *S. brevispinis* is discussed in Section 9.3.4.4.

Recommendations for the grouped quota for S. brevispinis, and S. pinniger

The equilibrium yields for *S. brevispinis* and *S. pinniger* in Areas 5A and 5B are 750 and 500 t for a total of 1250 t. Over the last five years the *S. brevispinis* production has averaged 70% of the two species'combined yield. A 1250 t quota would therefore be expected to result in yields of 875 t of *S. brevispinis* and 375 t of *S. pinniger*. As the *S. brevispinis* landings would then be exceeding the sustainable level, we recommend a combined quota of 1100 t which can be raised to 1250 t should the proportion of *S. brevispinis* not significantly exceed 60%. The conservative and non-sustainable grouped options are suggested to be 500 and 2000 t.

5. Region: Hecate Strait

Recommendations for Pacific cod

The current low level of abundance of Pacific cod in Hecate Strait appears to be one more nadir in the historic quasi-cyclic oscillations. These oscillations reflect the variable recruitment, which in turn appears to be largely determined by factors other than fishing--water temperature is currently considered to be an important factor. While adverse (warm) water temperatures during 1981-84 preclude any immediate improvement in recruitment, fishing effort (and presumably F) has declined substantially since 1981-82.

Two alternative yield options are recommended, based largely on potential risk -- one optimistic and the other cautious. The optimistic yield option recommends no regulation, based on the assumption that the fishery is largely self-regulating. That is, effort will not rise before cod abundance rises. The cautious yield option recommends a ceiling on landings, not to exceed the mean of previous nadir ($x = 1,700$ t). This would ensure that no sudden increase effort would occur, for whatever cause.

Recommendations for Dover sole

Current catch levels are 86% of the estimated MSY while current effort levels are 78% of the estimated optimum effort level. This indicates that true MSY may be higher than 800 t. Results of the analysis must be interpreted with caution due to the low coefficient of determination.

A sustainable yield option of 800 t, equivalent to MSY for the Gulland analysis, should be designated as a quota.

Recommendations for walleye pollock

An unlimited yield option is proposed for this region. The stock is currently underexploited due to intermittent availability and weak market demand.

Recommendations for silvergrey rockfish

There is no firm indication that the stock is being over-harvested so quotas are unchanged from those recommended for 1984: a conservative yield of 300 t; an equilibrium yield of 600 t; and a non-sustainable yield of 1000 t. Landings from 5D are low enough that this quota could be applied to the two areas if it would simplify management.

Recommendations for yellowtail and canary rockfishes

Fisheries for *S. flavidus* and *S. pinniger*, in Areas 5C and 5D, continue to be inconsequential in recent years. Qualified (25%) landings in 1983 equalled 36 and 38 t respectively. In the absence of significant fisheries, no new information has become available since the last published stock assessments.

Recommended quota options are shown below:

	5C			5D		
S. flavidus	100	200	400	150	350	500
S. pinniger	150	250	500	n.d.	100	200
Combined	200	400	800	150	400	600

These are suggested as guidelines only. Should they be reached, then consideration could be given to raising the quotas based on size composition, species proportions and the progress of other fisheries. The two areas combined if it would ease management, yields would be the sum of the area yields shown.

4.1. Area 5C. Hecate Strait

Recommendations for rock sole

No significant decline in abundance has been detected in the LPUE analysis, however, recruitment remains at a low level.

Production models applied to Area 5C rock sole (Stocker, 1981) indicated a maximum sustainable yield of 500 t for the stock. This yield was to be achieved by setting a catch quota of 500 t. The catch quota resulted in supply and marketing problems for industry because the quota was reached early in the fishing season.

A separate analysis determined that over the last 25 years if trips >30,000 lb. per boat were eliminated, production for 5C rock sole would stablize near MSY levels. The trip limit could also be removed to take advantage of strong year-classes.

Sustainable: A trip limit of 30,000 lb (14 t) is recommended due to the low recruitment mode for rock sole in Area 5C. This is recommended to prevent the possibility of recruitment overfishing.

Recommendations for Pacific ocean perch (Moresby Gully)

The age spectrum of this stock in the landings is extensive (5-72 y) and the short exploitation history precludes any age-structured analysis. It is believed that this stock experienced little or no exploitation prior to 1980 and if so, a rare opportunity to examine stock dynamics at high biomass levels exists. It is imperative from a scientific management view, to determine the response of this stock to exploitation at the level of fishing mortality associated with maximum long-term yield. From the detailed analysis of the GIG stock, this should occur at approximately F = 0.06 and that yield (2000 t) is identified as the sustainable yield in Table 1. Yields associated with other options (conservative = 1700 t, non-sustainable = 2500 t) have also been calculated on the basis of the GIG analysis. We anticipate that sustainable yield for this stock will continue to be identified with a level of F approximately equal to M for at least a decade, to permit evaluation of such a harvest strategy. Increasing exploitation prior to that period will obscure our only opportunity to conduct such an evaluation.

Recommendations for yellowmouth rockfish (Moresby Gully)

No analytic studies of S. reedi in MOR have been conducted. The paucity of both statistical and biological data for this area precludes any quantitative analysis. The incidental nature of the fishery suggests limited opportunity for control of the harvest. It is unlikely that a directed fishery is even possible for S. reedi in this area, given the unavoidable incidence of S. alutus that would occur in such a fishery. The foregoing suggests that grouped management of the two species is the most viable strategy. Table 9.2.1.4 presents this option for S. reedi, yields being assessed through the proportional incidence of S. reedi in the S. alutus fishery (1980-84 average = 0.1217) applied to the yield options identified for S. alutus. Conservative, sustainable and non-sustainable yield options are thus 200 t, 240 t and 300 t, respectively.

4.2. Area 5D. Hecate Strait

Recommendations for English sole

While the landing statistics indicate that English sole in Area 5D sustained a substantial amount of effort during 1977-81, length frequency anomalies and age composition data indicate the population is relatively stable. For example an above average year-class was produced in 1977 and the percentage of older fish in the population has remained fairly constant.

In the past, catch quotas set for English sole in Area 5D have been exceeded (almost doubled in 1981) because the species is taken mostly incidentally in a fishery where the major species (Pacific cod) harvest is not restricted.

Currently, the English sole population in Area 5D appears in a good state, though cohort analysis results indicate that the stock is currently lower than MSY levels (75% of MSY).

Sustainable: 600 t -- equivalent to maximum yield for stock at 75% of MSY levels.

High Risk: 800 t -- equivalent to the long-term sustainable yield for English sole in Area 5D.

Recommendations for rock sole

The response surface analysis indicates that maintenance of a minimum stock size is important to recruitment for rock sole in Area 5D.

In the late 1960s, the stock size for rock sole in Area 5D fell below the level indicated by the model for optimum production. The LPUE time series shows a decline since that time. The present population is estimated to be slightly higher than in the late 1960s, and not below the critical level for reproduction.

In the previous stock assessment document, a yield of 250 t was estimated for rock sole in Area 5D. A separate analysis determined that a 30,000 lb. trip limit for rock sole in Hecate Strait would help to achieve this yield level.

Rebuilding: It is difficult to evaluate the effects of the trip limit on rock sole production in Area 5D, but in 1981 the 250 t level previously mentioned was exceeded. A more conservative trip limit of 20,000 lb. would help to prevent this, but would also curtail rock sole production in Area 5C.

Sustainable: The 30,000 lb. (14 t) trip limit will help to keep Area 5D rock sole stock size above the "critical" level.

6. Region: West coast of Queen Charlotte Islands (Area 5E)

Recommendations for silvergrey, yellowtail, and canary rockfish

Yield options are suggested as guidelines only and are unchanged from those of 1984. Guideline combined yields for S. brevispinis, S. flavidus, and S. pinniger are 200 t for 5E North and 950 t for 5E South. There is not sufficient background information to suggest conservative or non-sustainable yields.

6. Region: West Coast of Queen Charlotte Islands (South of 54° lat.)

Recommendations for Pacific ocean perch, yellowmouth rockfish, and rougheye rockfish

The statistics of the fishery involving S. reedi in the area are cause for concern. It is difficult to determine the cause for the recent decline in LPUE although several factors may contribute. Firstly, the fishery in recent years has not achieved the desired species contributions to grouped quotas due to ineffective enforcement of time/area closures. This resulted in truncation of the fishing seasons with the effect that little fishing occurred in the fall, when catch rates for S. reedi are generally higher. Secondly, the LPUE for 1981 is somewhat anomalous with the adjacent values; a cause for which may be the low percentage of the total catch covered by interview.

Lastly, the 1984 statistic does not include the full calendar year and is subject to change.

No changes in the individual species yield options from the 1984 assessments are recommended (Table 1). However, if management opts for a continuation of assemblage management for this area, a shift in the periods of opening is suggested in an attempt to optimize the S. reedi contribution to the total catch. This shift is based upon a review of monthly landing statistics over the period 1977-83, and suggests a closed period from July-August.

6. Region: West coast of Queen Charlotte Islands (North of 54' lat.)

Recommendations for Pacific ocean perch, yellowmouth and rougheye rockfish

The 1984 fishery is believed to have further reduced the existing low level of biomass for rockfishes, north of 54°. Considerably greater yield from these stocks could be realized if they could be rehabilitated. Yield options of Table 1 are derived from biomass estimates and subsequent fishery results. The conservative yields are identified as zero tonnes for all species; sustainable yields are those arising from non-directed fishing only; while non-sustainable yields are 200 t and 250 t for S. alutus and S. aleutianus separately or 450 t in total.

Table 1. Yield options for slope rockfishes (*S. alutus*, *S. reedi*, *S. aleutianus*). Yields in tonnes.

			Harvest strategy		
Area	Species	Cluster options	Conservative	Sustainable	Non-sustainable
3C	*S. alutus*	A	n.d.	300	500
3D	*S. alutus*	A	250	350	500
5A/B (Goose Is. & Mitchell's gullies)	*S. alutus*	A	850	1050	1300
	S. reedi	A	200	350	500
	Slope rockfish	C	1050	1400	1800
5C (Moresby Gully)	*S. alutus*	A	1700	2000	2500
	S. reedi	A	200	250	300
	Slope rockfish	C	1900	2250	2800
5E(S)	*S. alutus*	A	400	600	1000
	S. reedi	A	400	600	1000
	S. aleutianus	A	100	250	500
Jan.-June	Slope rockfish	C	300	500	900
Sept.-Dec.	Slope rockfish	C	600	900	1300
5E(N)	*S. alutus*	A	0	n.d.[a]	200
	S. aleutianus	A	0	n.d.	250
	Slope rockfish	C	0	n.d.	450

[a] n.d. -- non-directed fishery.

S. alutus = Pacific ocean perch
S. reedi = yellowmouth rockfish
S. aleutianus = roughеye rockfish

Cluster option A = single species
Cluster option C = full clustering of all species.

Table 2. Shelf rockfish (*S. brevispinis*, *S. flavidus*, *S. pinniger*).

			Harvest strategy		
Area	Species	Option	Conservative/ rebuilding	Equilibrium/sustainable	Non-sustainable
3C	*S. brevispinis*	A	non-directed	100	200
	S. flavidus		n.d.	200 n.d.	a
	S. pinniger		n.d.	200 n.d.	a
	Shelf rockfish	C	n.d.	300 n.d.	a
3D	*S. brevispinis*	A	150	350	700
	S. flavidus		n.d.	100	250
	S. pinniger		250	500	750
	Shelf rockfish	C	250	750	1500
5A+B	*S. brevispinis*	A	400	750	1200
	S. flavidus		500	1500	2500
	S. pinniger		200	500	1000
	Shelf rockfish[b]	B	500	1100	2000
	S. flavidus		500	1500	2500
	Shelf rockfish	C	600	1500(2500)[d]	4000
5C	*S. brevispinis*	A	300	600	1000
	S. flavidus		100	200	400
	S. pinniger		150	250	500
	Shelf rockfish[c]	B	200	450	800
	S. brevispinis		300	600	1000
	Shelf rockfish	C	400	700(1050)	1500
5D	*S. brevispinis*	A	combined with Area 5C		
	S. flavidus		150	350	500
	S. pinniger		n.d.	100	200
	Shelf rockfish	C	200	500	750

Table 2 (cont'd)

Area	Species	Option	Harvest strategy Conservative/ rebuilding	Harvest strategy Equilibrium/sustainable	Harvest strategy Non-sustainable
5E(N)	*S. brevispinus*		-------------100[e]-----------------		
	S. flavidus	A	-------------200[e]-----------------		
	S. pinniger		-------------200[e]-----------------		
	Shelf rockfish	C	-------------200[e](or free fishing)-		
5E(S)	*S. brevispinis*	A	--------------350[e]-----------------		
	S. flavidus		--------------200[e]-----------------		
	S. pinniger		--------------400[e]-----------------		
	Shelf rockfish	C	--------------950[e]-----------------		

[a] Joint international quotas recommended if yields exceed suggested equilibrium levels.

[b] *S. brevispinis* and *S. pinniger*.

[c] *S. flavidus* and *S. pinniger*.

[d] Total to be considered if the preliminary landings reflect expected clusters. n.d.=non-directed fishery.

[e] Little knowledge of resource status.

A = single species.

B = partial clustering of selected species considered under A.

C = full clustering of all species.

S. brevispinis = silvergrey rockfish

S. flavidus = yellowtail rockfish

S. pinniger = canary rockfish

Table 3. Summary of Groundfish yield options.

1. REGION: Coastwide

Species	Yield option 1	Yield option 2
Sablefish	Conservative level 4,000 t	High risk 5,000 t
Dogfish[a]	Conservative 8000 - 15,000 t	High risk 25,000 t

[a] Other than Strait of Georgia.

Regulatory measures suggested:

No change from 1984 on a biological basis.

2. REGION: Strait of Georgia (Area 4B)

Species	Yield option 1	Yield option 2
Dogfish	Conservative 3,000 t	High risk None suggested
Pacific hake	Conservative 10,000 t	High risk 15,000 t
Walleye pollock	Conservative 2,350 t	High risk 10,500 t

Regulatory measures suggested:

Dogfish: Delete 1984 reference to additional quotas in area combinations: 12, 13, 15 and 19, 20. Otherwise the same as 1984.

Lingcod:
1. The 1984 closure should remain unchanged.
2. A minimum size limit for sports line-caught lingcod of 58 cm is recommended.

3.1. Area: 3C. Lower West Coast of Vancouver Island

Species	Yield option 1	Yield option 2	Yield option 3
Lingcod	Conservative 900 t	High risk 1,400 t	None suggested
Pacific cod	Closure, Jan.	One week opening each month; Jan., Feb., Mar.	No limitations

Table 3 (cont'd)

Species	Yield option 1	Yield option 2	Yield option 3
Pacific hake	45,000 t	67,000 t	None suggested
Pacific ocean perch	Conservative Option, Sustainable Option, Non-sustainable Option--Refer to Table 1.		
Silvergray rockfish	Refer to Table 2.		
Yellowtail rockfish	Refer to Table 2.		
Canary rockfish	Refer to Table 2.		
Species group	Refer to Table 2.		

3.2. Area: 3D. Upper West Coast of Vancouver Island

Species	Yield option 1	Yield option 2	Yield option 3
Lingcod	Conservative 450 t	High risk 500 t	None suggested
Pacific ocean perch	Conservative Option, Sustainable Option, Non-sustainable levels are proposed. Refer to Table 1.		
Silvergray rockfish	Conservative, sustainable, and non-sustainable levels are proposed for the shelf species below. Refer to Table 2.		
Yellowtail rockfish	Refer to Table 2.		
Canary rockfish	Refer to Table 2.		
Species group	Refer to Table 2.		

4. REGION: Queen Charlotte Sound

Species	Yield options
Pacific ocean perch	Tonnage levels for three yield options are proposed for the rockfishes: conservative, sustainable, and non-sustainable.
Yellowmouth rockfish	Refer to Table 1 for Pacific ocean perch and yellowmouth rockfish.
Silvergray rockfish	Refer to Table 2 for silvergrey, yellowtail, and canary rockfishes.

Table 3 (cont'd)

Species	Yield options
Yellowtail rockfish	A group quota is also suggested (Table 2).
Canary rockfish	

	Conservative yield option	High risk yield option
Lingcod	1,100 t	1,200 t

5. REGION: Hecate Strait

Species	Yield options
Dover sole	800 t suggested as a quota.
Pacific cod	No regulations are recommended, though the stock is low and a 1,700 t ceiling on catch is supportable.
Silvergray rockfish	Levels proposed are: Conservative Option, Sustainable Option, Non-sustainable Option. The yield option formerly ascribed to Area 5C should be applied to the entire Region. Refer to Table 2.
Yellowtail	Three levels are proposed. It is recommended that the quotas for areas 5C/5D be combined for a Regional quota.
and Canary rockfish	Refer to Table 2.

5. REGION: Hecate Strait. Area 5C.

Species	Yield options
Pacific ocean perch	Three levels of yield option are recommended to be implemented as a quota. Refer to Table 1.
Yellowmouth rockfish	A grouped option including Pacific ocean perch is preferred at the sustainable level. Refer to Table 1.

Regulatory Measures:

Rock sole	The continuation of a 30,000 lb (14 t) trip limit is recommended.
Pacific ocean perch	A split season is again a possibility as for 1984.

Table 3 (cont'd)

5. REGION: Hecate Strait. Area 5D.

Regulatory Measures:

Rock sole	A trip limit of 30,000 lb (14 t) should be continued.

6. REGION: West Coast of Queen Charlotte Islands (5E)
(south of 54°00 N latitude)

Species	Yield options
Yellowmouth rockfish	Three levels of yield option are presented. A group quota is recommended and a new seasonal split. Refer to Table 1.
Rougheye rockfish	Same.
Pacific ocean perch	Same.
Silvergray rockfish	Three levels of yield option are presented. A group quota is recommended. Refer to Table 2.
Yellowtail rockfish	Same.
Rougheye rockfish	Same.

6. REGION: West Coast of Queen Charlotte Islands (5E)
(North of 54°00 N latitude)

Separate recommendations are made for this area for the same species as were made south of 54°N. As to the south in 5E, a species-group option is preferred.

Refer to Table 1 and Table 2.

2.0. LINGCOD

by A. J. Cass.

2.1. Coastwide

Yield options are not proposed on a coastwide basis.

2.2. Strait of Georgia and vicinity (Area 4B)

2.2.1. Introduction

The lingcod resource in the Strait of Georgia is an important component of sports hook and line and SCUBA spear fisheries. It is also fished commercially mainly by handline (jig) vessels. Lesser amounts are taken by commercial trawl vessels.

Despite a long history of exploitation, data collection and analysis have not been particularly well developed (Ketchen 1980a; Westrheim 1980, Stocker 1981).

Tagging studies indicate adult lingcod are relatively sedentary and that lingcod in the Strait of Georgia probably exist as a number of localized stocks (Hart 1943; Chatwin 1956; Cass et al. 1983a). Nevertheless, delineation of stocks in the Strait of Georgia and adjacent inside waters of Vancouver Island (Area 4B) has not been clearly defined.

Studies to determine the age composition, growth and mortality of lingcod were initiated in 1979. Except for growth, production rates of lingcod in the Strait of Georgia are poorly determined.

2.2.2. Landing statistics

Commercial landings have historically been taken principally by handline/troll gear. Except for a brief flurry of commercial trawling near Victoria during 1959-61, landings by other commercial gears have been insignificant (Table 2.2.1). Lingcod in the Strait of Georgia underwent a relatively intense period of commercial exploitation beginning in the 1920s and ending in the early 1960s. Landings peaked during 1936 at about 4500 t (Ketchen et al. 1983). Since the early 1960s commercial landings have undergone a marked decline (Fig. 2.2.1). Landings declined from an average of 1300 t/yr during 1951-62 to an average of less than 400 t/yr during 1973-83. The main areas of commercial exploitation have been in the northern area of the Strait of Georgia near Campbell River (MSA 13), the southern Gulf Islands near Porlier Pass (MSA 17), and in the eastern Strait near Pender Harbour (MSA 16) (Table 2.2.2). Since 1969 the commercial fishery in MSA 16 has been of little importance. Commercial handline landings from MSA 13 and 17 have together accounted for about 61% of the commercial production during 1970-83.

During 1967-81, landing statistics published by the Department of Fisheries[1] have also included an estimate of fishing effort (days-fished).

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[1] Source: British Columbia Catch Statistics, Department of Fisheries and Oceans; Annual Reports 1951-81.

Table 2.2.1. Commercial handline-troll and trawl landings of lingcod (t) from the Strait of Georgia and vicinity (Area 4B), 1951-83.

Year	Handline/ troll[a]	Trawl[b]	Total
1951	1279.5	48.1	1327.6
1952	1488.8	54.0	1542.8
1953	1179.2	28.1	1207.3
1954	1449.4	68.0	1517.4
1955	1220.1	50.6	1270.7
1956	1512.1	55.7	1567.8
1957	1539.7	42.0	1581.7
1958	1445.6	74.6	1520.2
1959	1183.0	336.4	1519.4
1960	1250.6	184.1	1434.7
1961	1157.7	102.1	1259.8
1962	1272.9	75.4	1348.3
1963	989.3	39.6	1028.9
1964	870.4	90.3	960.7
1965	779.7	93.8	873.5
1966	771.3	53.7	825.0
1967	778.6	51.3	829.9
1968	728.1	83.9	812.0
1969	875.7	65.6	941.3
1970	788.6	48.0	836.6
1971	564.0	55.5	619.5
1972	513.4	34.5	547.9
1973	371.8	14.8	386.6
1974	363.7	49.4	413.1
1975	330.5	33.1	363.6
1976	315.5	43.4	358.9
1977	412.5	16.2	428.7
1978	452.6	42.5	495.1
1979	503.7	25.2	528.9
1980	350.5	33.5	384.0
1981	336.0	63.1	399.1
1982	388.2	79.0	467.2
1983	273.0	85.3	358.3

[a] Source: 1951-82. British Columbia Catch Statistics. Department of Fisheries and Oceans, Annual Reports. 1983: preliminary data.

[b] Source: 1951-53. British Columbia Catch Statistics, Department of Fisheries and Oceans, Annual Reports. 1954-83: PBS computer files.

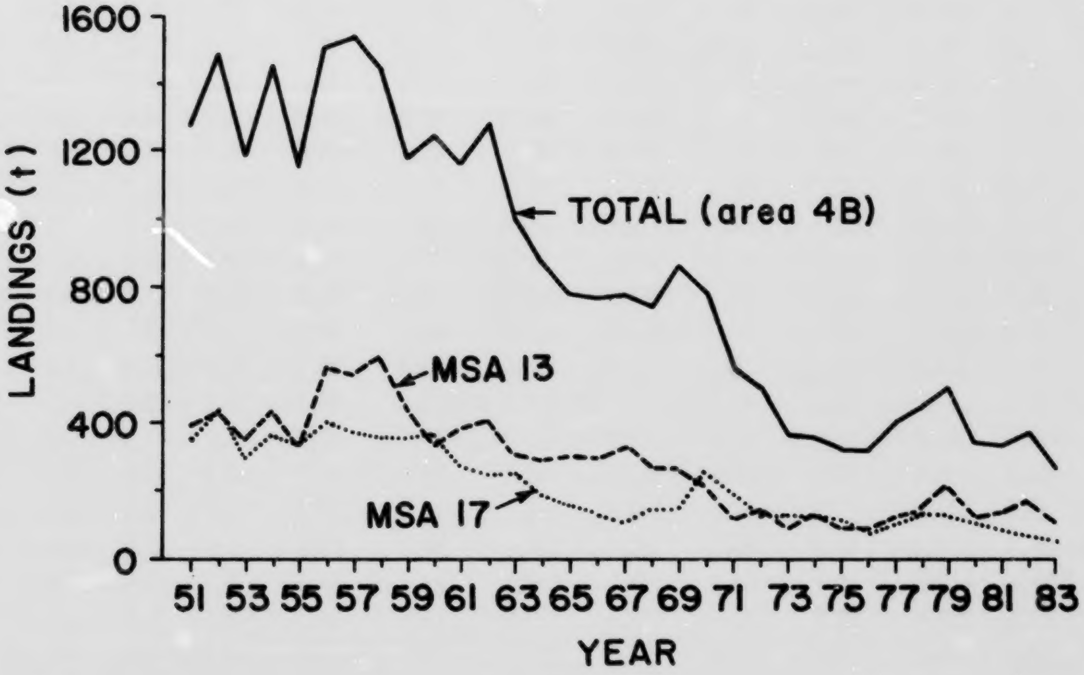

Fig. 2.2.1. Commercial handline -troll landings of lingcod showing the total landings from the Strait of Georgia and vicinity (Area 4B) and from the main areas of the fishery (MSA 13 and 17), 1951-83.

Table 2.2.2. Commercial handline-troll landings of lingcod (t) from the Strait of Georgia and vicinity (Area 4B) by Minor Statistical Area, 1951-83.[a]

	Minor Area										
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1951	9.3	397.3	79.8	39.3	95.4	357.2	253.2	30.0	17.2	1.7	0.3	1279.5
1952	7.2	426.1	83.5	72.9	167.3	435.6	235.5	28.6	25.2	7.0	0.0	1488.8
1953	3.3	345.8	84.3	44.8	162.3	288.2	179.0	38.9	28.1	4.4	0.1	1179.2
1954	5.6	437.3	157.6	21.5	243.1	361.7	169.1	33.7	13.2	4.8	1.8	1449.4
1955	2.2	329.9	84.4	58.8	241.6	338.8	112.3	44.1	8.0	0.0	0.0	1220.1
1956	3.9	564.7	96.3	60.6	235.0	396.8	106.9	44.1	2.1	1.2	0.6	1512.1
1957	4.9	542.4	82.4	107.1	286.0	362.6	96.9	54.0	2.3	0.3	0.8	1539.7
1958	11.2	497.2	105.6	79.3	229.7	350.2	93.5	73.7	4.5	0.6	0.0	1445.6
1959	10.8	338.3	85.6	31.2	166.8	343.7	85.3	104.5	0.8	0.6	15.4	1183.0
1960	18.7	336.9	110.7	47.1	157.3	372.2	97.0	82.8	23.1	1.3	3.5	1250.6
1961	24.5	393.1	91.4	45.6	170.6	268.4	64.0	63.3	29.2	5.1	2.4	1157.7
1962	151.0	407.5	111.2	60.4	138.1	240.9	57.2	75.8	19.1	7.8	4.1	1272.9
1963	59.5	301.4	63.1	29.4	158.7	248.3	44.7	63.5	20.5	0.1	0.1	989.3
1964	31.9	288.8	43.3	18.7	168.6	191.5	53.8	52.6	20.7	0.1	0.4	870.4
1965	26.5	303.2	52.0	6.6	133.8	153.4	50.0	39.3	10.5	0.0	4.6	779.7
1966	36.6	298.7	61.7	21.7	117.1	125.2	61.2	33.0	16.1	0.0	0.0	771.3
1967	43.4	331.2	55.6	19.8	128.2	106.4	69.5	17.7	6.4	0.0	0.4	778.6
1968	43.6	272.4	53.6	22.0	101.6	156.1	53.0	14.7	10.5	0.0	0.8	728.1
1969	61.5	275.6	71.8	67.3	149.6	151.4	59.9	35.3	3.1	0.0	0.1	875.7
1970	37.9	219.2	37.8	80.5	83.4	264.7	34.9	23.2	6.5	0.0	0.5	788.6
1971	31.6	118.7	30.2	66.2	77.1	196.7	22.5	18.7	2.3	0.1	0.0	564.0
1972	27.5	152.8	23.2	42.9	76.5	129.8	19.6	38.1	2.4	0.0	0.5	513.4
1973	7.5	86.4	8.8	57.0	27.5	120.8	34.4	27.5	1.3	0.6	0.0	371.8
1974	14.4	129.6	13.8	22.5	18.8	125.2	21.9	15.0	1.9	0.0	0.6	363.7
1975	6.3	93.3	9.4	68.9	11.3	117.1	11.3	8.1	4.4	0.0	0.6	330.5
1976	8.8	95.8	12.5	70.1	16.3	82.0	13.2	7.5	5.6	3.1	0.6	315.5
1977	23.2	127.7	31.3	53.8	18.2	98.3	40.7	15.0	2.5	1.9	0.0	412.5
1978	12.4	151.8	19.3	34.5	11.0	138.0	35.9	41.4	4.1	0.0	4.1	452.6
1979	17.9	212.5	31.7	29.0	11.0	131.1	24.8	29.0	12.4	4.1	0.0	503.7
1980	13.8	129.7	12.4	26.2	11.0	104.9	20.7	23.5	5.5	1.4	1.4	350.5
1981	16.0	138.4	21.0	34.4	10.1	82.4	13.5	16.3	3.3	0.0	0.6	336.0
1982	16.8	177.3	41.4	45.3	7.7	60.9	19.0	156.5	2.3	0.4	1.2	388.2
1983	14.1	111.0	17.4	32.8	6.6	53.1	16.0	14.0	4.4	3.3	0.3	273.0

[a] Source: 1951-82 British Columbia Catch Statistics, Department of Fisheries and Oceans, Annual Reports. 1983: preliminary data.

While the bulk of handline effort has historically been directed at lingcod, increasing amounts of this effort have been re-directed to nearshore rockfishes since the late 1970s. In an attempt to eliminate extraneous fishing effort directed to other species, we have selected only that effort expended by vessels known to fish exclusively for lingcod.

Landings per unit effort (LPUE) were calculated from 7 vessels for the two principal areas of commercial exploitation, namely MSA 13 and 17. Total annual effort was estimated by dividing the total landings by the corresponding LPUE. The result is a 17-year time-series of landings, effort and LPUE (Table 2.2.3 and 2.2.4).

It is important to note that by selecting specific vessels as a means of eliminating extraneous effort, we may be incorporating serious biases in our estimates of LPUE and total effort. These vessels have remained in the fishery long after the majority of other vessels have dropped out. As such we have probably selected the most successful fishermen of a once larger fishing fleet. During periods of low stock abundance, these fishermen may be more adept at re-directing their effort further afield or to smaller numbers of aggregations, thereby maintaining high levels of catch and LPUE as stocks decline.

In MSA 13, LPUE increased from 365 kg/boat-day in 1967 to 749 kg/boat-day in 1980 (Table 2.2.3). LPUE then declined to a low of 264 kg/boat-day in 1983. Landings and effort have remained at low levels since 1970 (Fig. 2.2.2).

In MSA 17, LPUE has increased from 96 kg/boat-day in 1967 to 223 kg/boat-day in 1981 (Table 2.2.4). LPUE in 1983 was lower than average at 142 kg/boat-day. Landings and effort have declined fairly steadily in recent years and have been at record low levels since 1981 (Fig. 2.2.3).

Not until 1980 was a concerted effort made to estimate landings of lingcod by the sports hook and line fisheries. The most reliable estimates of sport catches are based on creel and overflight surveys (Shardlow and Hoyt 1984). These surveys provide estimates of the number of lingcod landed during 1980-83. Sports landings accounted for an estimated 57% of the number of lingcod landed and an average of 13% of the total all-species sports landings from the Strait of Georgia during 1980-83. During 1980-83 an average of 106,000 pieces/yr were landed by sports fishermen. Landings declined from 1980 to 1983 by 46% from 137,000 pieces to 74,000 pieces, mainly as a result of declining catches in the northern Strait of Georgia (MSA 13, 14, and 15) (Table 2.2.5).

It is widely recognized that sports fishing activity in the Strait of Georgia underwent a rapid expansion during the 1960s. There are, however, no reliable data to quantify the rate of increase in sports fishing intensity during that period. Published estimates indicate sports effort continued to increase throughout the 1972-76 period (Argue et al. 1977). More recent data indicate sports fishing intensity during the 1980-82 period has remained at levels similar to those of the 1972-76 period (Shardlow and Hoyt 1984). It is not possible to estimate the amount of sports effort directed specifically at lingcod. We do believe that sports fishing for lingcod has increased in proportion to sports fishing activity in the Strait of Georgia since the 1950s.

Table 2.2.3. Commercial handline/troll landing statistics for lingcod in the northern Strait of Georgia (MSA 13), 1967-83.

Year	Landed catch (t)[a]	LPUE (t/boat-day)[b]	Total effort (h)
1967	331.2	.365	907
1968	272.4	.393	693
1969	275.6	.524	526
1970	219.2	.533	411
1971	118.7	.394	301
1972	152.8	.508	301
1973	86.4	.494	175
1974	129.6	.751	172
1975	93.3	.482	194
1976	95.8	.519	184
1977	127.7	.517	247
1978	151.8	.614	247
1979	212.5	.511	416
1980	129.7	.749	173
1981	139.4	.622	224
1982	177.3	.387	458
1983	111.0	.264	420

[a] Source: 1967-82 British Columbia Catch Statistics, Department of Fisheries and Oceans, Annual Reports. 1983 preliminary data.

[b] Source: Department of Fisheries and Oceans sales slip computer files based on selected vessels known to fish exclusively for lingcod.

Table 2.2.4. Commercial handline/troll landing statistics for lingcod in the southwestern Strait of Georgia (MSA 17), 1967-83.

Year	Landed catch (t)	LPUE (t/boat-day)	Total effort (h)
1967	106.4	.096	1108
1968	156.1	.117	1334
1969	151.4	.090	1682
1970	264.7	.152	1741
1971	196.7	.148	1329
1972	129.8	.104	1248
1973	120.8	.171	706
1974	125.2	.162	773
1975	117.1	.182	643
1976	82.0	.158	519
1977	98.3	.173	568
1978	138.0	.186	742
1979	131.1	.222	591
1980	104.9	.161	652
1981	83.0	.223	372
1982	60.9	.155	393
1983	53.1	.142	374

[a] Source: 1967-82 British Columbia Catch Statistics, Department of Fisheries and Oceans, Annual Reports. 1983 preliminary data.

[b] Source: Department of Fisheries and Oceans sales slip computer files. Values of LPUE were estimated for selected vessels known to fish exclusively for lingcod.

Table 2.2.5. Number of lingcod landed (x1000) in the sport line fishery in the Strait of Georgia by Minor Statistical Area, 1980-83.[a]

	Minor Area									
Year	13	14	15	16	17	18	19	28	29	Total
1980	44.3	14.1	2.5	21.8	19.3	8.8	15.6	4.2	6.1	136.7
1981	31.9	14.7	6.8	10.0	10.1	11.6	25.3	5.8	8.6	124.8
1982	16.0	6.1	1.6	20.1	9.6	7.5	12.6	6.4	5.4	85.3
1983	16.2	2.3	1.1	20.1	7.0	6.2	9.9	6.7	4.3	73.8

[a] Landings were estimated from results of the Strait of Georgia creel survey (Shardlow and Hoyt 1984).

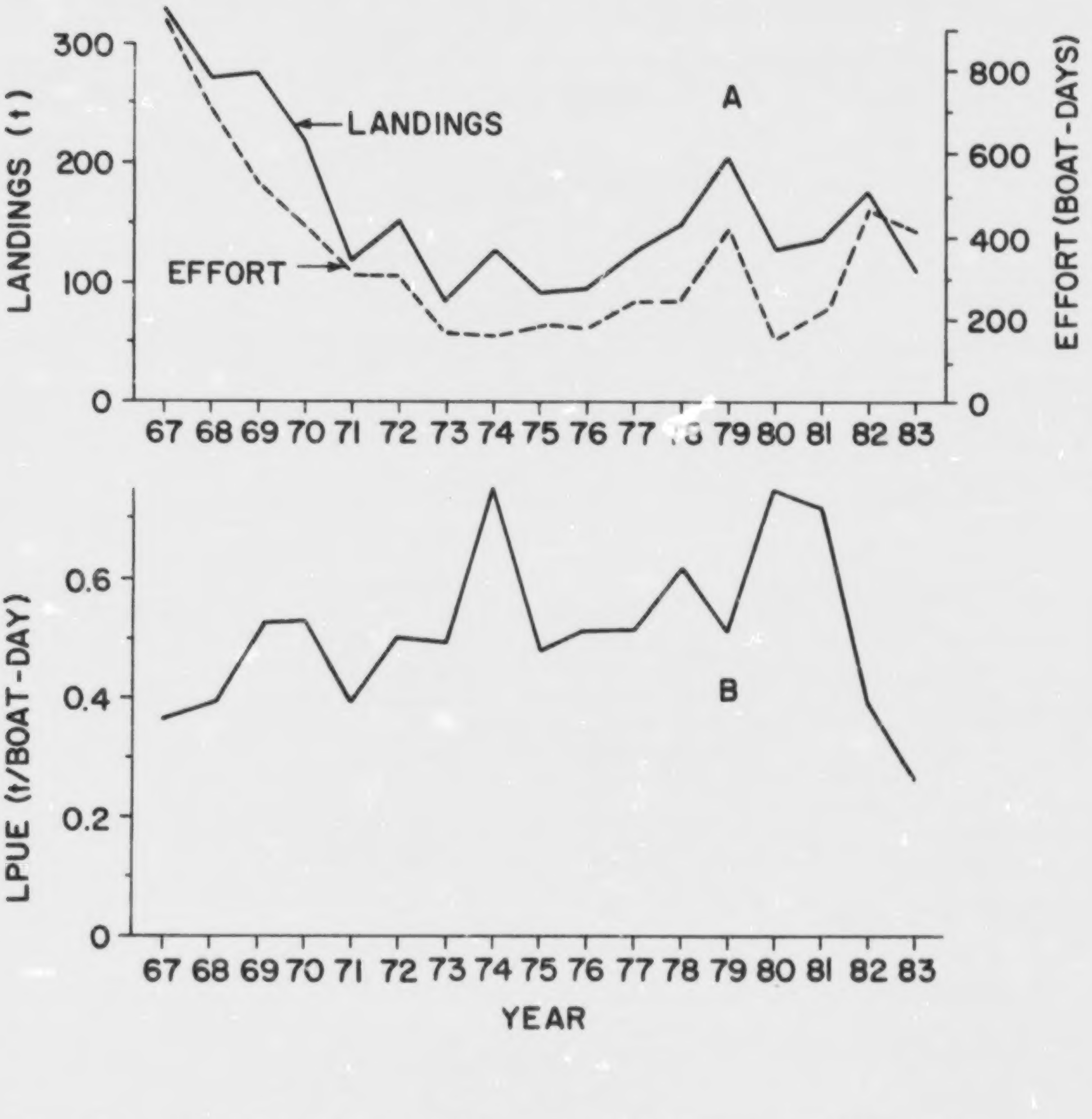

Fig. 2.2.2. Lingcod landing statistics showing A) landings and effort and B) LPUE trends for the commercial handline-troll fishery in MSA 13, 1967-83.

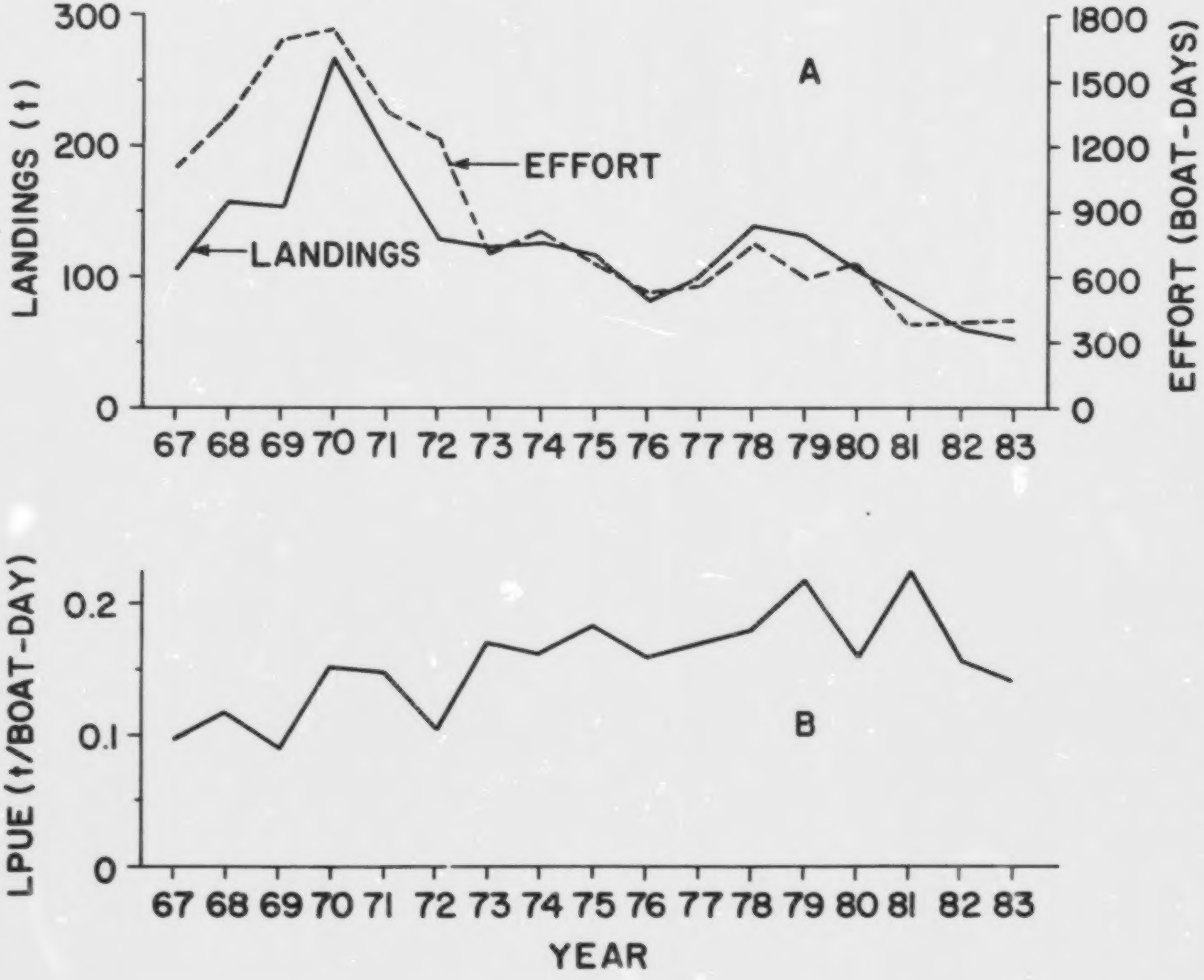

Fig. 2.2.3. Lingcod landing statistics showing A) landings and effort and B) LPUE trends for the commercial handline-troll fishery in MSA 17, 1967-83.

Lingcod is also the principal target species of SCUBA-oriented spear fishermen. Reliable estimates of catches by spear fishermen have not been determined. However, SCUBA removals may be significant, particularly in localized nearshore areas of the Strait of Georgia.

2.2.3. Stock assessment

Without a suitable time-series of sports fisheries data it is not possible to estimate the current productivity of stocks in the Strait of Georgia.

The collapse of the commercial handline fishery is believed to reflect a decline in abundance. The reason for the decline is not clear. However, overfishing is suspected.

While the representativeness of commercial LPUE is questionable, the increasing trend in LPUE in MSA 13 and 17 during 1967-81 along with falling landings and effort indicates abundance may have increased slightly during this period as a result of a decline in commercial fishing pressure. However, without an adequate time-series of sports catches and effort data, the relationship between LPUE and total effort cannot be properly examined.

The decline in handline LPUE and sports landings in MSA 13 after 1981 indicates stocks in that area may have undergone a more recent decline.

Tag recapture data and biological samples collected in 1983 from sports and commercial line fisheries indicate these fisheries are selective for different sizes of lingcod (Fig. 2.2.4.). Of the total number of tagged and untagged lingcod sampled from the sports fishery, 50% were less than 60 cm in fork length, whereas nearly 100% of the lingcod in commercial samples were greater than 60 cm. Studies off the west coast of Vancouver Island indicate most lingcod less than 60 cm in length, particularly female lingcod, are immature (Cass et al. 1984a). While similar studies have not been conducted in the Strait of Georgia, a significant portion of the landings may now consist of immature fish.

In an attempt to rebuild stocks, the existing fishing closure (December 1-March 31) was extended in 1979 (November 15-April 14) to more suitably cover the pre-spawning aggregation, spawning and nesting periods in the Strait of Georgia (Low and Beamish 1978; Ketchen 1980a, Westrheim 1980, Stocker 1981). During 1980-82, larval and juvenile surveys were conducted in the southern Strait of Georgia to monitor the effect of the closure on lingcod abundance (Cass and Scarsbrook 1984). Results of that study indicated the 1980 and 1981 year-classes were of above average strength. However, we cannot assess the impact of the closure on recruitment until we can determine the strength of these and succeeding year-classes during their presence in the fishable stock.

While not recommended as a management option in this document, if lingcod stocks remain at low levels we may consider additional rebuilding strategies such as minor area closures.

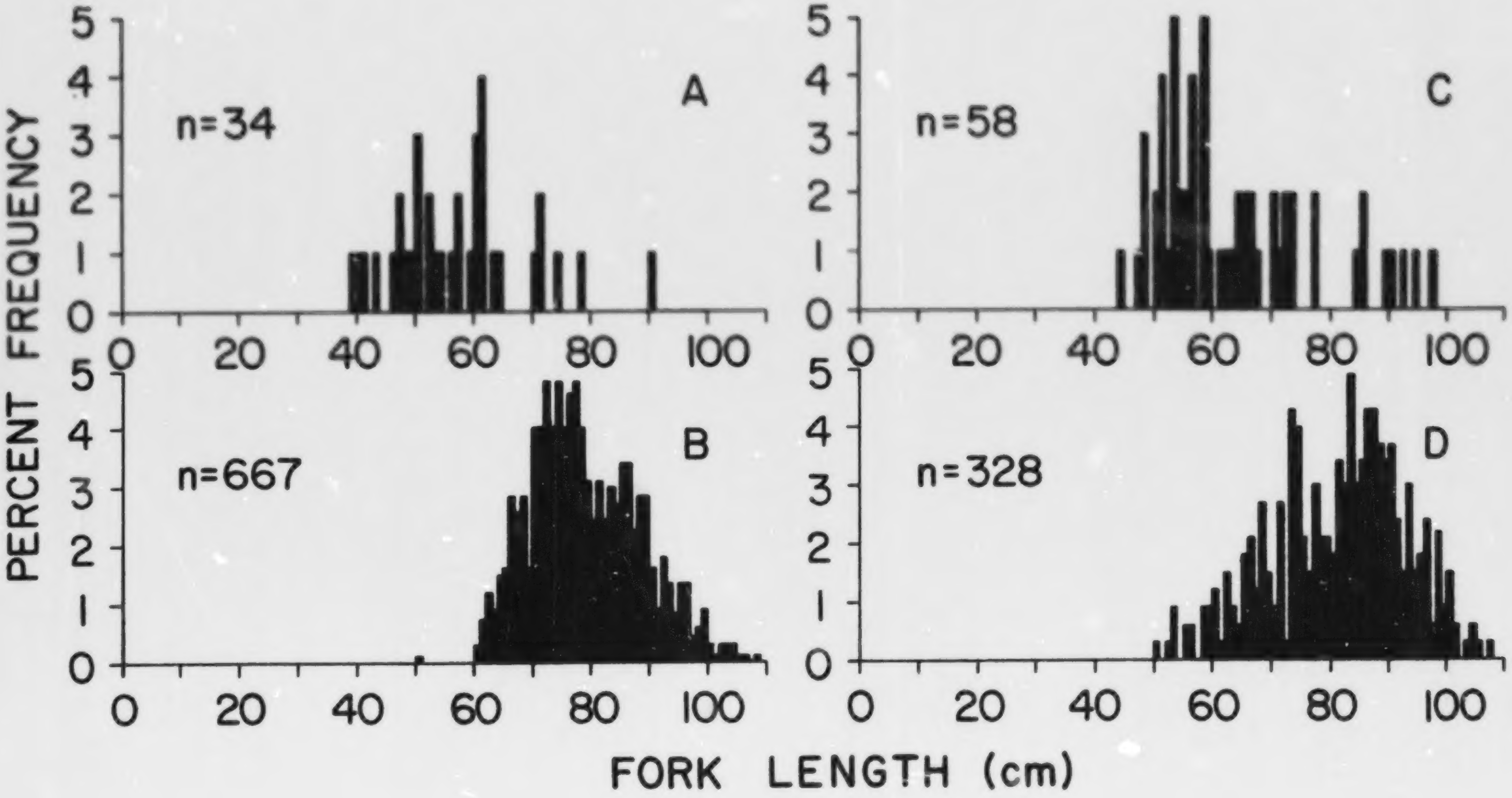

Fig. 2.2.4. Length-frequency histograms of lingcod in samples from A) the sports and B) commercial fisheries and tagged lingcod recovered in C) the sports and D) commercial fisheries in the Strait of Georgia during 1982-83.

2.2.4. Recommendations

Sufficient time has not elapsed to evaluate the impact of the extended winter fishing closure on recruitment. Therefore we recommend that the present lingcod closure be continued in 1985.

We further recommend a minimum size limit for sports line-caught lingcod, similar to the size limit for the commercial fishery (58 cm). The purpose of this recommendation is to reduce the removal of immature lingcod. This may be particularly relevant in MSA 13 where declining levels of sport catches and handline LPUE in recent years warrant additional concern for stocks in that area. The nature of the commercial handline fishery, whereby lingcod are routinely kept alive and results of tagging studies using hook and line capture methods (Cass et al. 1984) indicate lingcod caught by hook and line gear will have a high survival rate if returned to the ocean. The survival rate of discards will ultimately be determined by how much care is taken when removing the hook. We recognize that the practice of persistent fishing and discarding under-sized fish until a "keeper" is caught will dampen the benefits of a size limit. However, small lingcod appear to reside in shallower water than larger fish. Therefore sports effort could be re-directed to areas populated by larger lingcod, thereby directly reducing the catch of immature lingcod without a high discard rate.

2.3. West Coast Vancouver Island

2.3.1. Introduction

Lingcod off the west coast of Vancouver Island are caught primarily as a component of the multispecies bottom trawl fisheries. Lesser quantities are also caught by commercial handline and troll vessels. Commercial concentrations are found mainly off southwest Vancouver Island in the vicinity of La Pérouse Bank (Big Bank).

Tagging studies off Vancouver Island indicate adult lingcod move very little (Chatwin 1956; Reeves 1966, Cass et al. 1983a, 1983b). Nevertheless, stock boundaries have not been clearly defined. For present purposes we have assumed the lingcod resource exists as two separate stocks; one off southwest Vancouver Island (Area 3C) and one off northwest Vancouver Island (Area 3D).

2.3.2. Landing statistics

Standardized landing statistics for the 1956-83 period (Table 2.3.1 and Table 2.3.2) were determined using the Option-2 method of Westrheim (1983) and Westrheim and Foucher (unpublished data). Landings per unit effort (LPUE) were determined from interviewed trawl data for the May-September fishing season. Trawl landings during this period accounted for 82% of the annual production during 1956-83. LPUE for Area 3C was determined for combined data from the three principal fishing grounds; namely Big Bank, Swiftsure and Minor Statistical Area 24. LPUE for Area 3D was determined for all areas combined. Total effort for each area was calculated by dividing the total all-gear annual landings by the corresponding LPUE.

Commercial landings off Vancouver Island have undergone marked fluctuations during the 1956-83 period. In Area 3C, landings have ranged from a high of 2100 t in 1966 to a low of 450 t in 1978. Landings in 1982 (1730 t) and 1983 (1140 t) were above average (Table 2.3.1). Landings from Area 3D ranged from a high of 1000 t in 1968 to a low of 160 t in 1980. Since 1980, annual landings have been increasing. As observed in other offshore areas, the landed catch in 1983 was above-average and equalled 560 t (Table 2.3.2). Fishing effort and LPUE have also fluctuated with no apparent long-term trend during the 1956-83 period. As shown in Fig. 2.3.1 and Fig. 2.3.2 fluctuations in landings, particularly in Area 3C, have parallelled trends in LPUE and, to a lesser extent, fishing effort.

2.3.3. Growth and mortality

Routine sampling for age and growth off southwest Vancouver Island began in 1977. While the time-series is presently insufficient for age-structured analysis, we have estimated growth and mortality rates as inputs to yield per recruit analysis (Beverton and Holt 1957) and Deriso's (1980) delay-difference model.

Von Bertalanffy growth curves were fitted to length at age data from commercial samples for age 3-19 females and age 3-13 males. Research data for age 1-2 lingcod were included to adjust for otherwise biased growth rates for younger age groups. Von Bertalanffy parameters are as follows:

Table 2.3.1. Lingcod landing statistics for Area 3C, 1956-83.

Year	Landed catch Trawl (t)	Line (t)	Total (t)	LPUE (kg/h)	Effort (h)
1956	1151	67	1218	263	4640
1957	1070	123	1193	226	5275
1958	1047	56	1103	286	3855
1959	1742	67	1809	274	6600
1960	1867	94	1961	251	7809
1961	1972	51	2023	288	7025
1962	890	66	956	141	6756
1963	609	58	667	198	3366
1964	1127	42	1169	397	2945
1965	1812	55	1867	302	6188
1966	2030	80	2110	332	6355
1967	1779	119	1898	446	4259
1968	1661	76	1737	566	3071
1969	1054	88	1142	267	4280
1970	703	132	835	271	3077
1971	979	127	1106	200	5538
1972	625	141	766	96	8009
1973	876	84	960	258	3724
1974	1029	93	1122	209	5367
1975	1630	86	1716	247	6933
1976	1205	118	1323	132	10052
1977	844	136	980	121	8112
1978	360	92	452	97	4668
1979	602	86	688	160	4287
1980	623	97	720	155	4644
1981	603	240	843	144	5840
1982	1510	220	1730	295	5856
1983	970	167	1137	234	4858

Table 2.3.2. Lingcod landing statistics for Area 3D, 1956-83.

Year	Landed catch Trawl (t)	 Line (t)	 Total (t)	LPUE (kg/h)	Effort (h)
1956	164	124	288	316	913
1957	130	135	264	392	674
1958	110	120	230	211	1088
1959	64	93	157	529	297
1960	87	106	193	660	292
1961	200	115	315	400	786
1962	286	103	389	199	1959
1963	115	121	237	277	855
1964	226	85	310	391	794
1965	505	90	595	315	1886
1966	585	135	720	427	1686
1967	460	166	225	434	1442
1968	868	107	975	604	1616
1969	619	77	696	293	2371
1970	456	157	613	268	2285
1971	264	114	378	174	2173
1972	85	181	266	197	1346
1973	172	84	256	364	705
1974	242	113	356	559	634
1975	347	90	437	252	1733
1976	245	90	336	280	1199
1977	158	107	265	232	1141
1978	197	94	291	467	623
1979	105	76	180	178	1013
1980	86	70	156	87	1794
1981	75	108	183	206	887
1982	49	232	281	115	2430
1983	446	119	565	254	2220

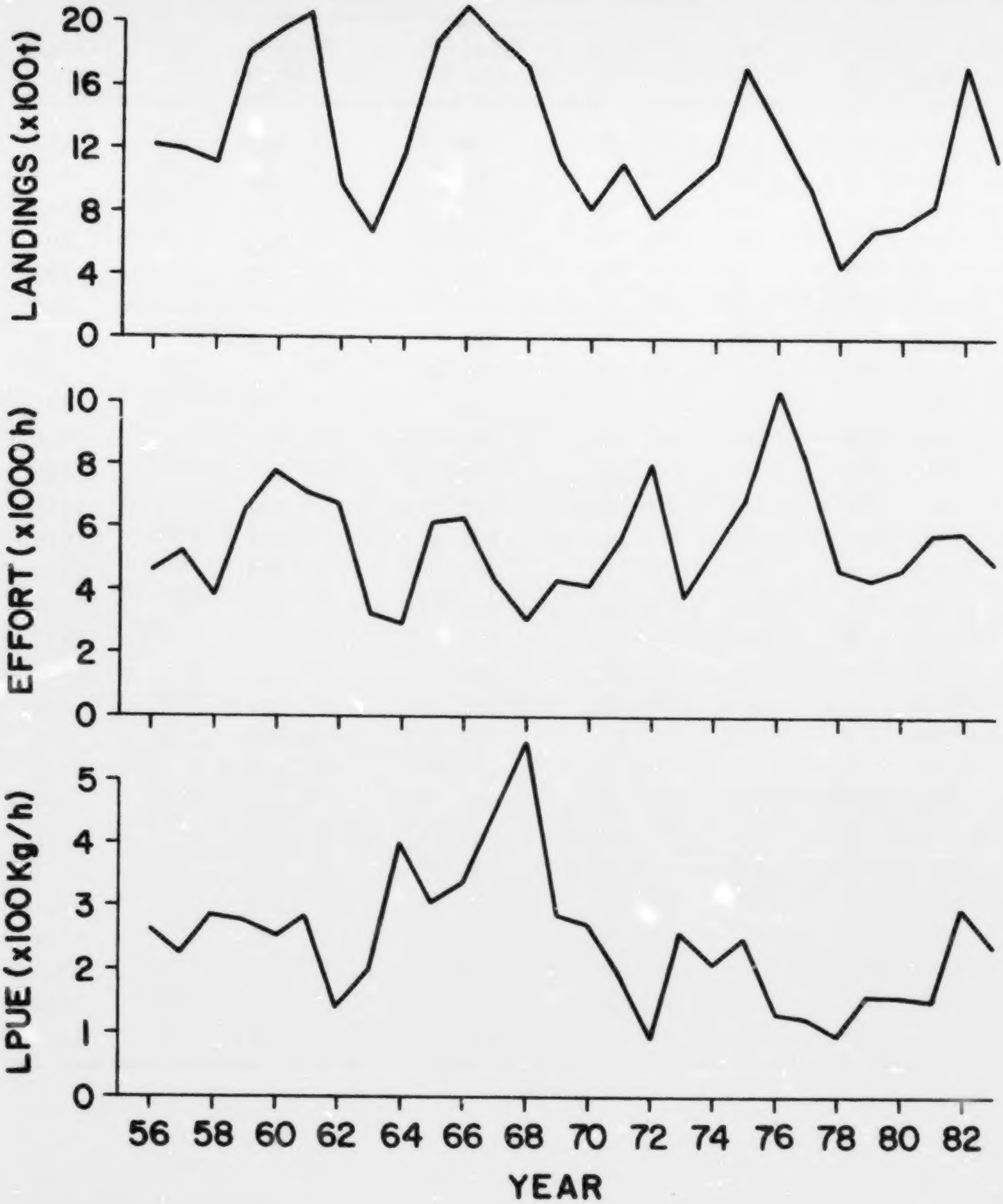

Fig. 2.3.1. Landings, effort and LPUE of lingcod in Area 3C, 1956-83.

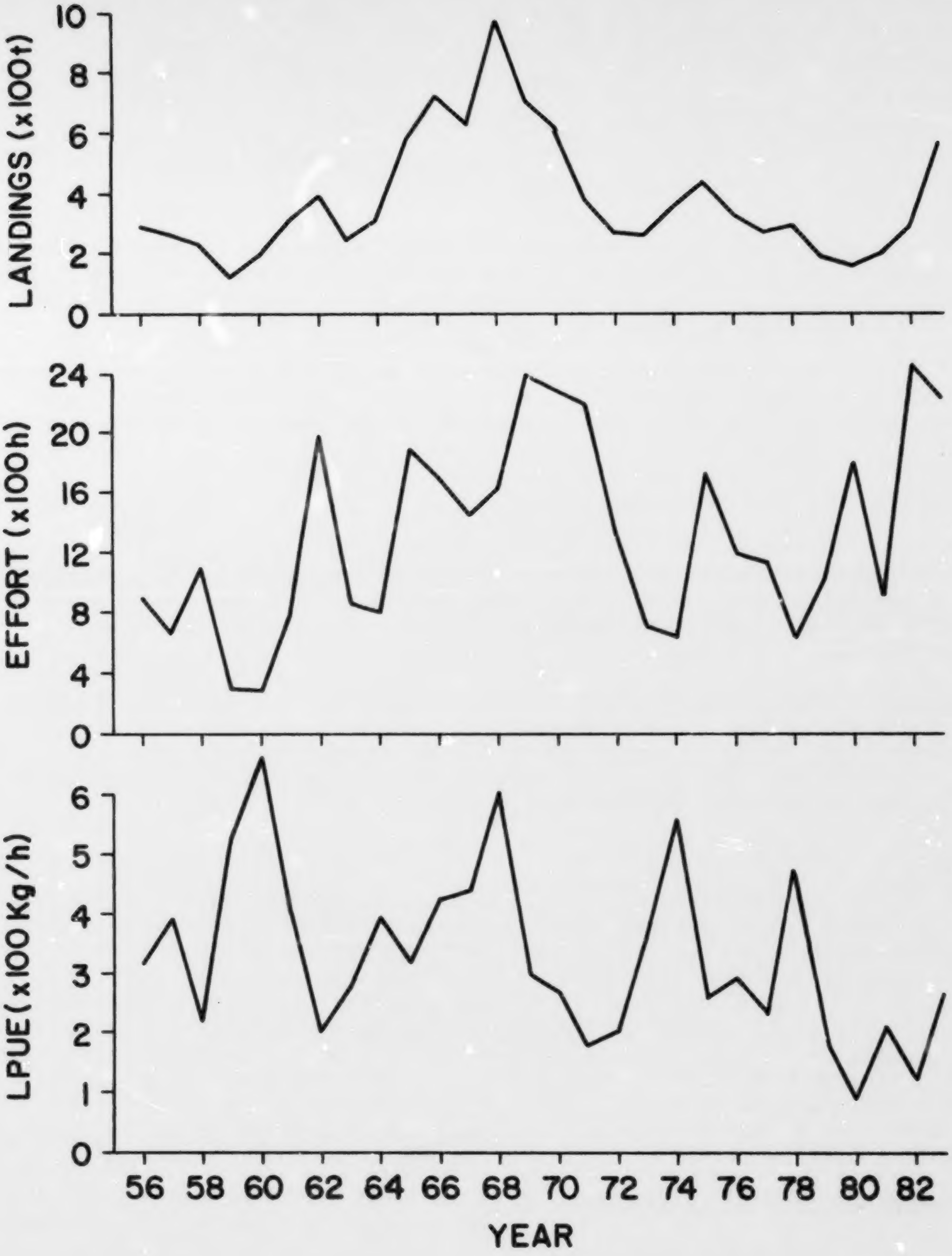

Fig. 2.3.2. Landings, effort and LPUE of lingcod in Area 3D, 1956-83.

	Male	Female
K	0.33	0.23
L_∞	78.8 cm	97.8 cm
T_0	-0.61 yr	-0.76 yr
W	5.5 kg	10.4 kg

The growth parameters reflect a marked sexual dimorphism in growth. After age 2, males are smaller than similar age females. The Brody growth coefficient (ρ) was estimated using the difference form of the Brody equation (Deriso 1980). For combined sexes age 4-11 yr ρ was determined to be 0.73.

Mortality rates were estimated from age composition data and from results of tagging studies (Cass et al. 1983b). Total mortality (Z) was estimated for combined sexes age 6-10 yr for the 1982-83 period whereby

$$Z = \log_e(N_t/N_{t+1})$$

The proportion (N) of age 6-8 yr at time t were compared to the proportion (N) of age 7-9 yr at time t+1. Similarly, age 7-9 yr were compared to age 8-10 yr and age 8-10 yr were compared to age 9-11 yr. The average estimate of Z during 1982-83 was 0.67.

Recoveries of tagged lingcod released and recovered off Vancouver Island during 1982 (Cass et al. 1983b) indicate the exploitation rate was about 0.34. Assuming natural mortality during the fishing period was negligible and using an average total mortality (Z) of 0.67, natural mortality (M) was estimated to be 0.26 (Ricker 1975, eq. 1.6).

2.3.4. Yield

Natural mortality and Von Bertalanffy growth parameters as estimated above were used to estimate yield-per-recruit isopleths (Beverton and Holt 1957) for male and female lingcod (Fig. 2.3.3 and Fig. 2.3.4).

Lingcod contribute significantly to the commercial trawl fisheries beginning at age 4. They fully recruit over ages 5-7 yr. The greatest increase in yield-per-recruit was over ages 4-6 yr at fishing mortality rates (F) ranging from 0.1-0.7. For females at a recruitment age of 5 yr the maximum yield was at an estimated $F = 0.5$. Because of the slower growth of males, the maximum yield at a recruitment age of 5 yr was at an $F = 0.7$. Little would be gained by increasing the age first fished beyond age 5.

Deriso's (1980) delay difference model.

This model incorporates growth, natural mortality and recruitment to predict biomass and yield.

The basic assumptions of the model are that growth in weight can be described by the difference form of the Brody equation and that natural

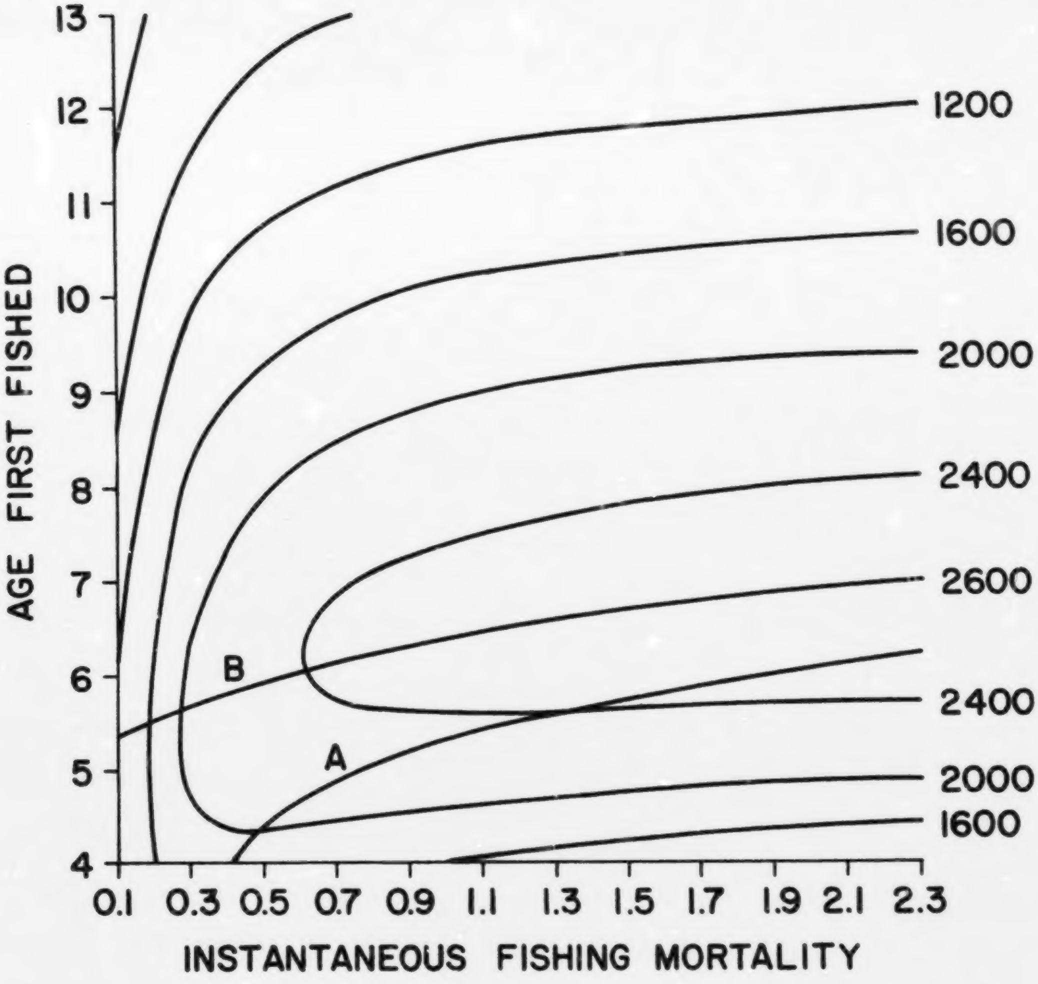

Fig. 2.3.3. Beverton-Holt yield isopleths for male lingcod off the west coast of Vancouver Island, showing A) F with best yield for given ages first fished and B) age first fished with best yield for given lives of F. Yield in grams per recruit is shown on the right.

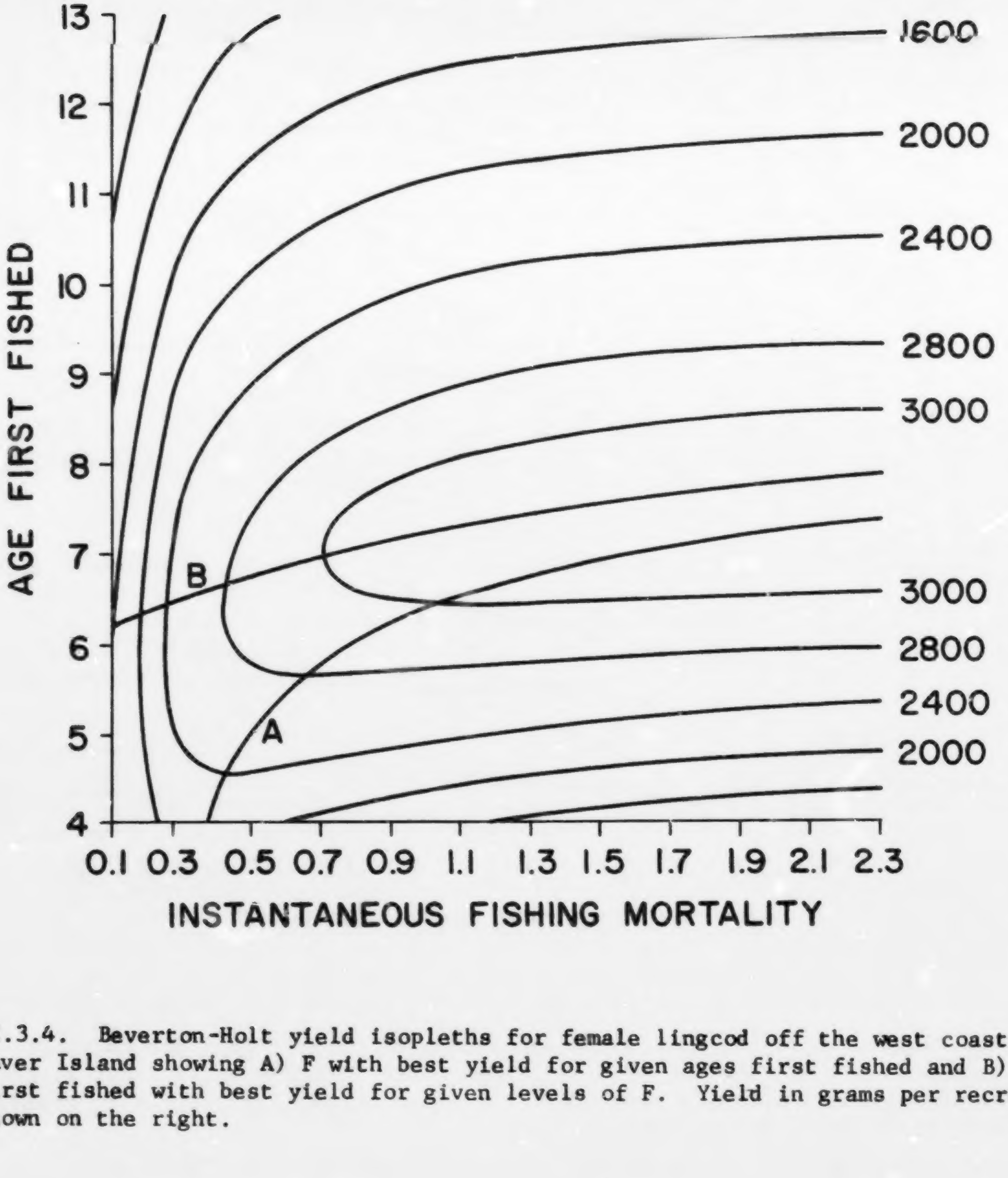

Fig. 2.3.4. Beverton-Holt yield isopleths for female lingcod off the west coast of Vancouver Island showing A) F with best yield for given ages first fished and B) age first fished with best yield for given levels of F. Yield in grams per recruit are shown on the right.

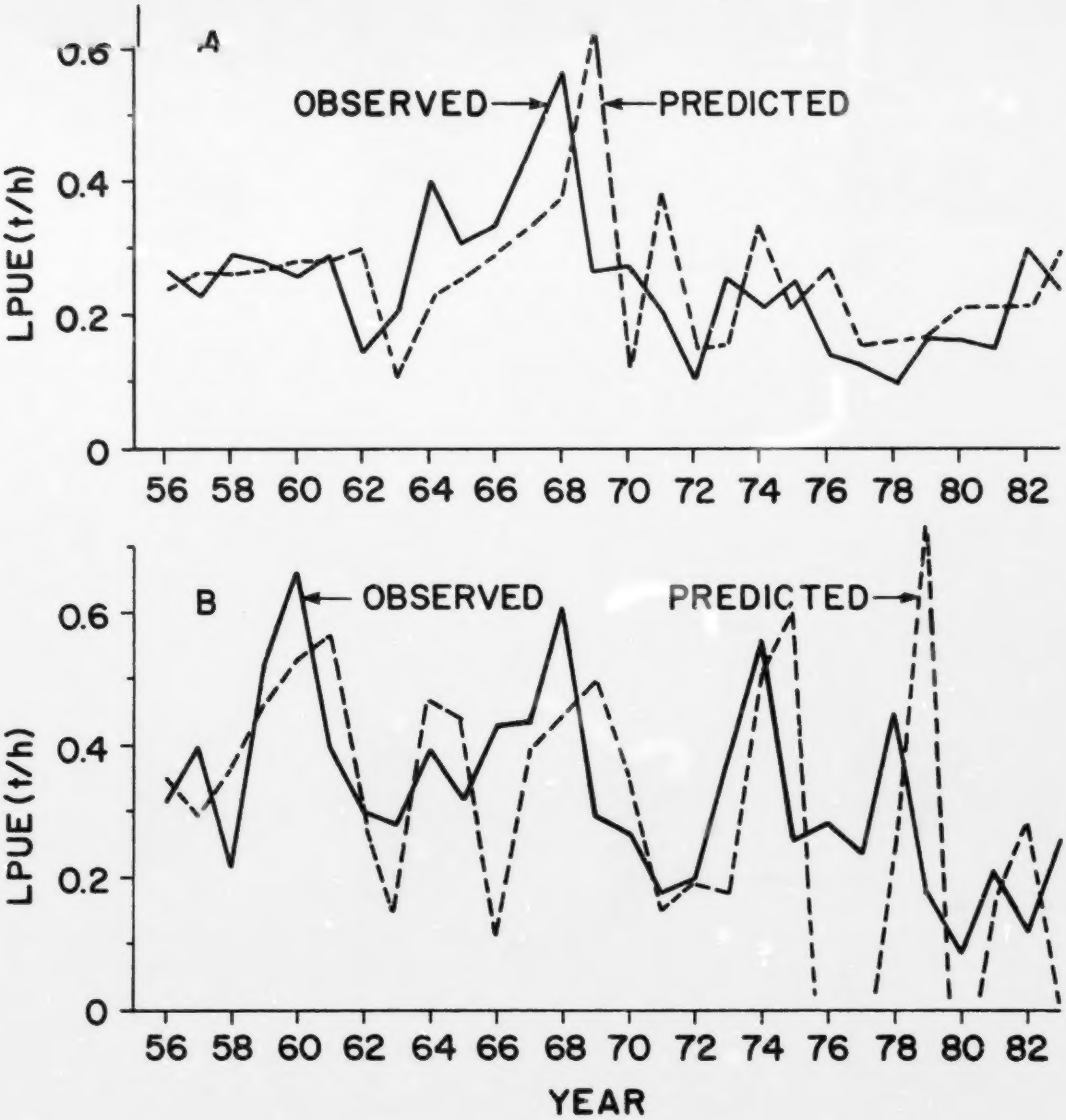

Fig. 2.3.5. Observed and predicted LPUE from Deriso's (1980) delay-difference population model for lingcod in A) Area 3C and B) Area 3D, 1956-83.

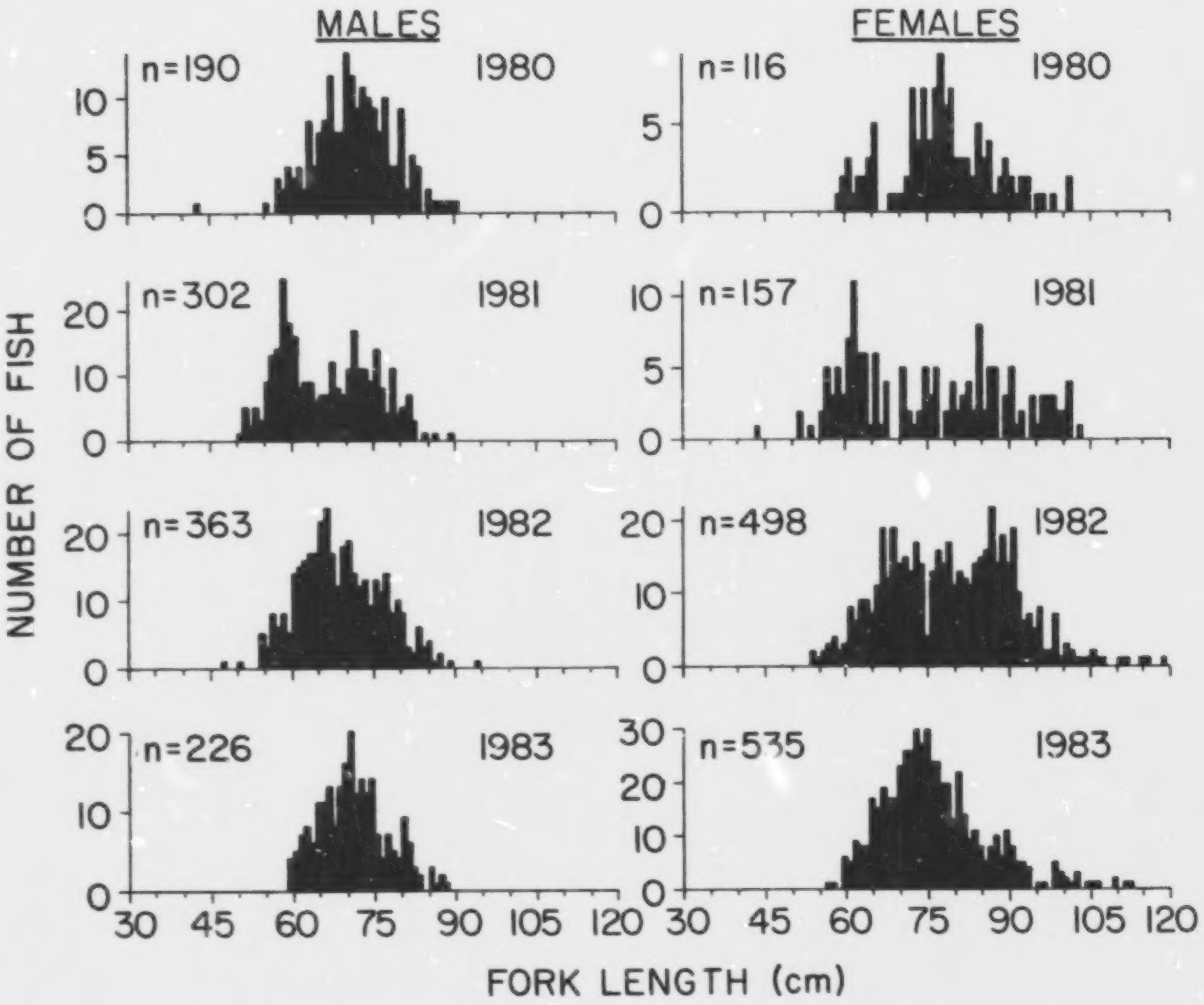

Fig. 2.3.6. Length-frequency histograms of lingcod in commercial trawl samples from off the west coast of Vancouver Island, Big Bank, 1980-83.

mortality and vulnerability to fishing are constant over all recruited age groups. For lingcod these assumptions appear to be reasonably satisfied.

The version of the model used in this analysis was from Walters' (1981) stock assessment software package. Estimates of growth (ρ) and natural mortality (M) used in the model are those determined in Sect. 2.3.3. Estimates of catchability and partial recruitment were also calculated independently of the model from tagging data (Cass et al. 1983b) and from age composition data (Cass, unpublished data), respectively. Recruitment parameters were fitted iteratively.

The best fits of the model (Fig. 2.3.5) were obtained by assuming that recruitment was constant. Results indicate yields at exploitation rates (μ) of 0.5 are sustainable. Estimates of maximum sustainable yields were 1002 t/yr for Area 3C and 440 t/yr for Area 3D. The estimates of MSY assume the production parameters used in the model are free of appreciable error. However, because the estimate of M is not particularly well determined (point estimate) we estimated a range of MSY values by using what we believe are extreme levels of M (0.2 and 0.4). Estimates of MSY for Area 3C at fixed M's of 0.2 and 0.4 were 913 t/yr and 1404 t/yr, respectively. Corresponding estimates of MSY for Area 3D were 458 t/yr and 507 t/yr.

2.3.5. Stock condition

Commercial production appears to be highly dependent on natural fluctuations in recruitment. Major surges in recruitment, such as occurred in the late 1960s and more recently since 1981, appeared as a coast-wide phenomenon in all offshore trawl fisheries. The most recent surge has occurred as a result of strong 1976-78 year-classes. These year-classes emerged as a prominent mode in length-frequency distributions during the 1981-83 fishery (Fig. 2.3.6). As a result of this recent surge in recruitment, stocks are currently at above-average levels.

2.3.6. Recommendations

Delay-difference modelling indicates yields are sustainable at exploitation rates of 0.5. Evidence from tagging studies (Cass et al. 1983b) indicates exploitation rates in 1982 were 0.34. These results indicate stocks off the west coast of Vancouver Island are currently under-exploited.

In this analysis we have attempted to present extreme ranges of yield options that reflect some uncertainty in our estimate of natural mortality. A conservative estimate of MSY for Area 3C is about 900 t/yr and 450 t/yr for Area 3D. Upper ranges for these areas are 1404 t/yr and 507 t/yr, respectively.

It is unlikely, given current market limitations, that exploitation rates can be increased. We therefore are not making any recommendations to alter harvesting strategies off the west coast of Vancouver Island.

2.4. Queen Charlotte Sound

2.4.1. Introduction

Lingcod have been a minor component of groundfish fisheries in Queen Charlotte Sound during most years since 1955. However, the surges in trawl production during 1966-68 and in 1982-83 raised the catch of lingcod during these periods to significant levels.

Commercially exploited stocks are located on the Cape Scott and Goose Island grounds, however stock delineation is poorly understood. For present purposes we have assumed that lingcod off Cape Scott (Area 5A) and on the Goose Island grounds (Area 5B) are two separate stocks.

2.4.2. Landing statistics

Landings per unit effort (LPUE) for the 1956-83 period were determined from interviewed trawl data for the May-September fishing period using Westrheim's (1983) Option-2 method. Effort was standardized for variations in vessel horsepower class according to Westrheim and Foucher (unpublished data). Total annual effort was estimated by dividing LPUE into corresponding total catches.

Landing statistics for Areas 5A and 5B are presented in Tables 2.4.1 and 2.4.2. Landings from the Cape Scott and Goose Island stocks contribute almost equally to the total commercial production from Queen Charlotte Sound. In both areas landings increased to above-average levels in 1966-68 and more recently have been increasing to high levels since 1981 (Fig. 2.4.1 and 2.4.2). Landings from Queen Charlotte Sound peaked at 2300 t in 1968 and again during 1983 at 1400 t. Trends in LPUE, particularly since 1968, have parallelled the trend in landed catch in both Area 5A and 5B.

2.4.3. Stock assessment

Commercial sampling for age, growth and mortality did not begin until 1978. Therefore, the time-series of catch-at-age data for Queen Charlotte Sound stocks is not sufficient for traditional age-structured analysis. Estimates of yield were determined using Walters' (1981) version of Deriso's (1980) delay difference model.

Except for growth, biological production rates are poorly determined. In the absence of independent estimates of natural mortality and catchability we assumed that these parameters were similar to those estimated for stocks off the southwest coast of Vancouver Island (see Sect. 2.3.). The Brody growth coefficient was estimated for combined sexes age 3-11 yr and equalled 0.83. An estimate of partial recruitment was determined from age composition data (Cass, unpublished data). Recruitment parameters were estimated iteratively in the model.

As was found for other offshore stocks, the best fit of the model (Fig. 2.4.3) was obtained using a constant recruitment rate. Results indicate that for both areas 5A and 5B yields are sustainable at exploitation rates of 0.4. The estimated maximum sustainable yield was 451 t/yr for Cape Scott stocks and 626 t/yr for Goose Island stocks. Using what we believe to be

Table 2.4.1. Lingcod landing statistics for Area 5A, 1956-83.

	Landed catch				
Year	Trawl (t)	Line (t)	Total (t)	LPUE (kg/h)	Effort (h)
1956	350	0.0	350	52	6792
1957	433	0.1	433	150	2896
1958	296	0.0	296	23	12883
1959	192	0.1	192	73	2648
1960	280	0.1	280	62	4521
1961	388	1	389	233	1669
1962	531	9	540	152	3548
1963	285	5	290	122	2380
1964	352	0.3	352	227	1555
1965	331	0.1	331	176	1886
1966	707	7	714	173	4118
1967	759	1	760	168	4510
1968	1227	1	1228	251	4889
1969	617	1	618	90	6853
1970	590	5	595	133	4475
1971	230	5	235	83	2829
1972	164	11	175	90	1946
1973	232	11	243	192	1261
1974	339	16	355	178	1993
1975	82	14	96	65	1481
1976	258	11	269	48	5619
1977	122	14	136	34	3997
1978	128	6	134	39	3465
1979	100	8	108	44	2435
1980	108	6	114	35	3262
1981	183	25	208	96	2167
1982	467	25	492	150	3282
1983	573	28	601	244	2462

Table 2.4.2. Lingcod landing statistics for Area 5B, 1956-83.

Year	Landed catch Trawl (t)	 Line (t)	 Total (t)	LPUE (kg/h)	Effort (h)
1956	250	3	253	78	3222
1957	170	2	172	118	1450
1958	277	1	278	119	2336
1959	429	1	430	203	2115
1960	378	12	390	127	3066
1961	323	31	354	113	3127
1962	407	28	435	146	2987
1963	357	25	382	155	2459
1964	335	7	342	122	2813
1965	566	9	575	150	3824
1966	827	20	847	211	4006
1967	901	24	925	247	3742
1968	1043	20	1063	275	3867
1969	517	12	529	86	6176
1970	390	32	422	55	7630
1971	415	11	426	72	5911
1972	476	36	512	47	10965
1973	349	11	360	29	12548
1974	532	19	551	683	6636
1975	429	22	451	47	9563
1976	346	30	376	48	7818
1977	257	12	269	59	4531
1978	162	10	172	42	4132
1979	242	11	253	48	5286
1980	300	10	310	46	6763
1981	548	24	572	153	3744
1982	579	29	608	190	3193
1983	772	26	798	255	3122

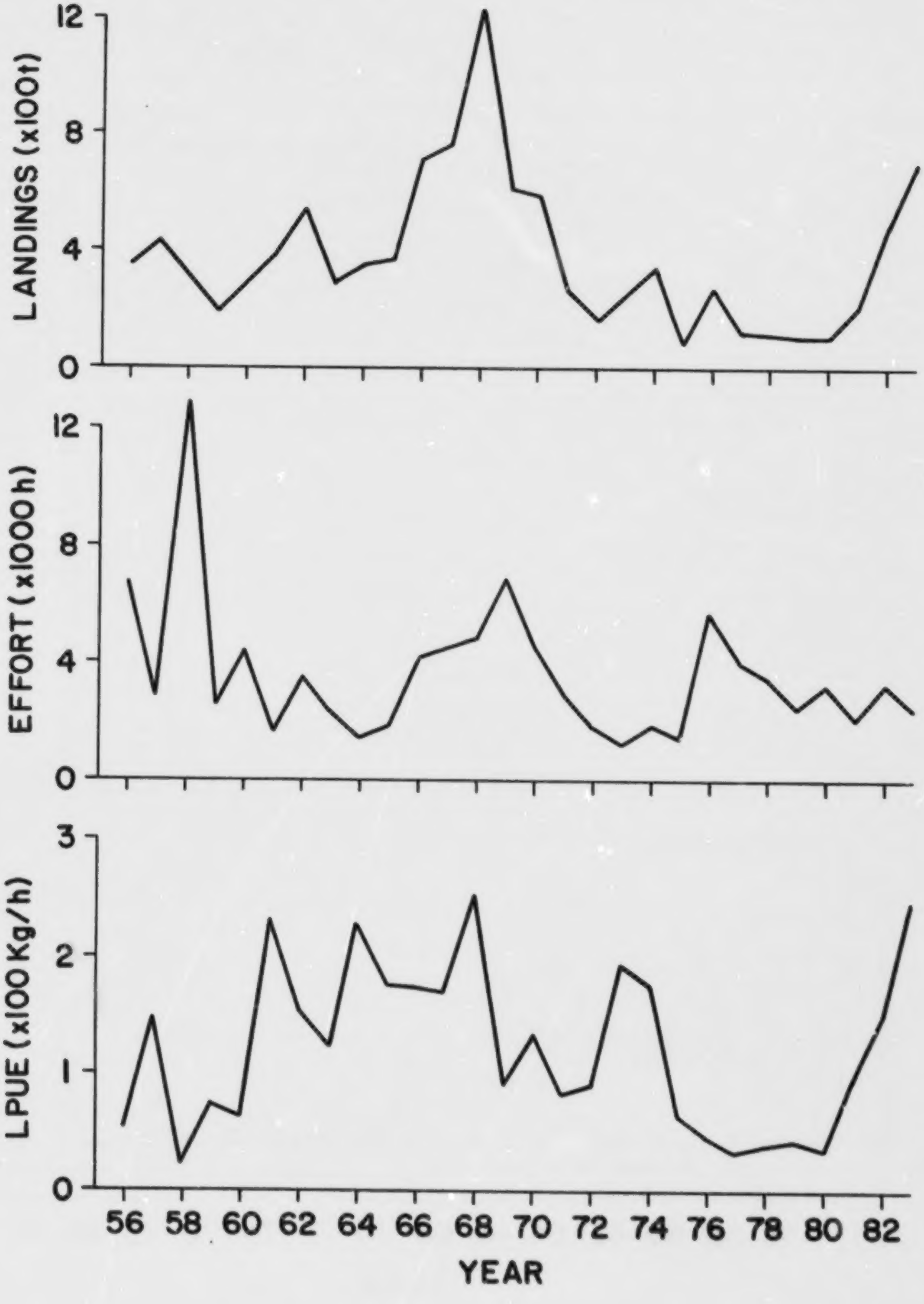

Fig. 2.4.1. Landings, effort and LPUE of lingcod in Area 5A, 1956-83.

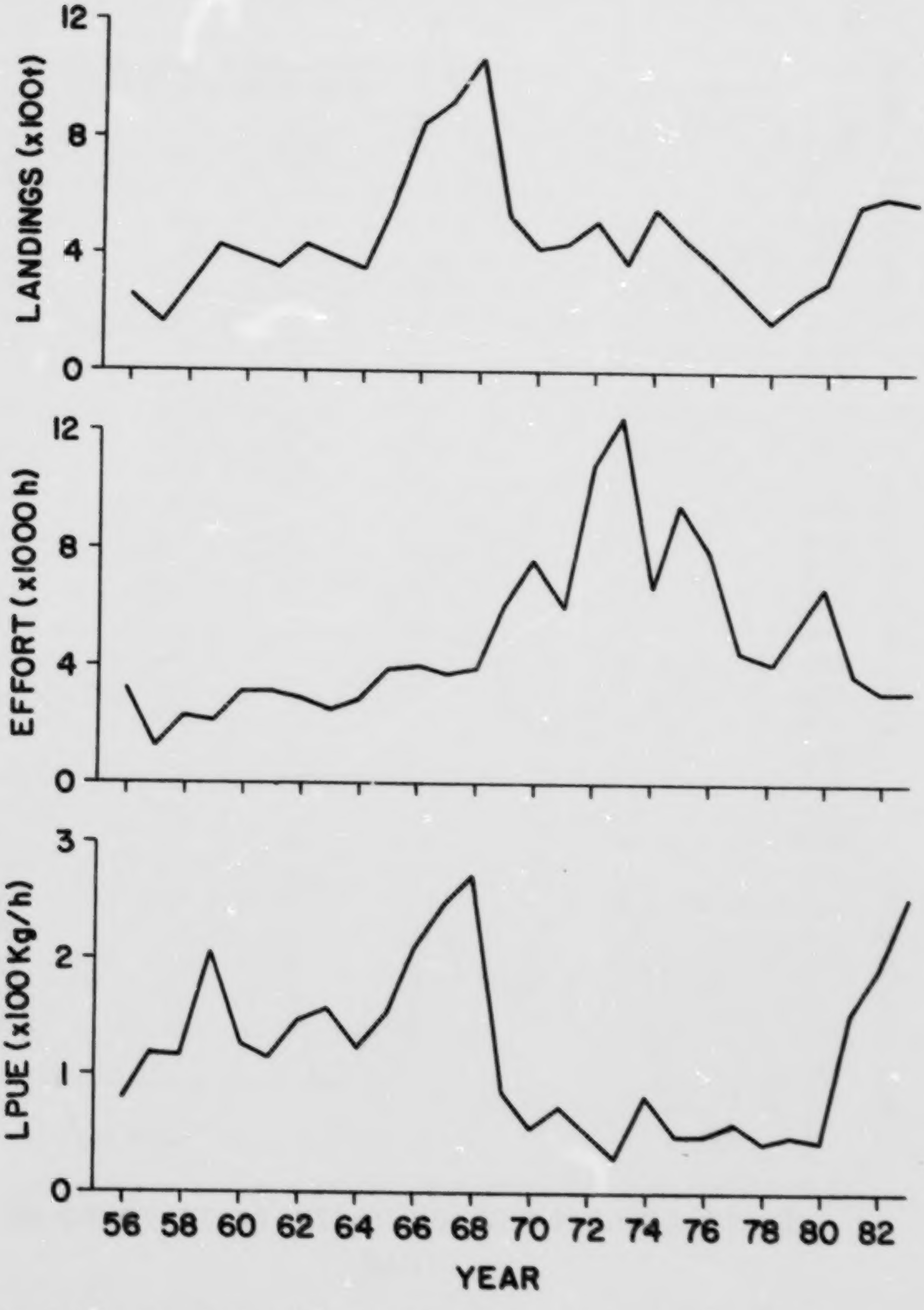

Fig. 2.4.2. Landings, effort and LPUE of lingcod in Area 5B, 1956-83.

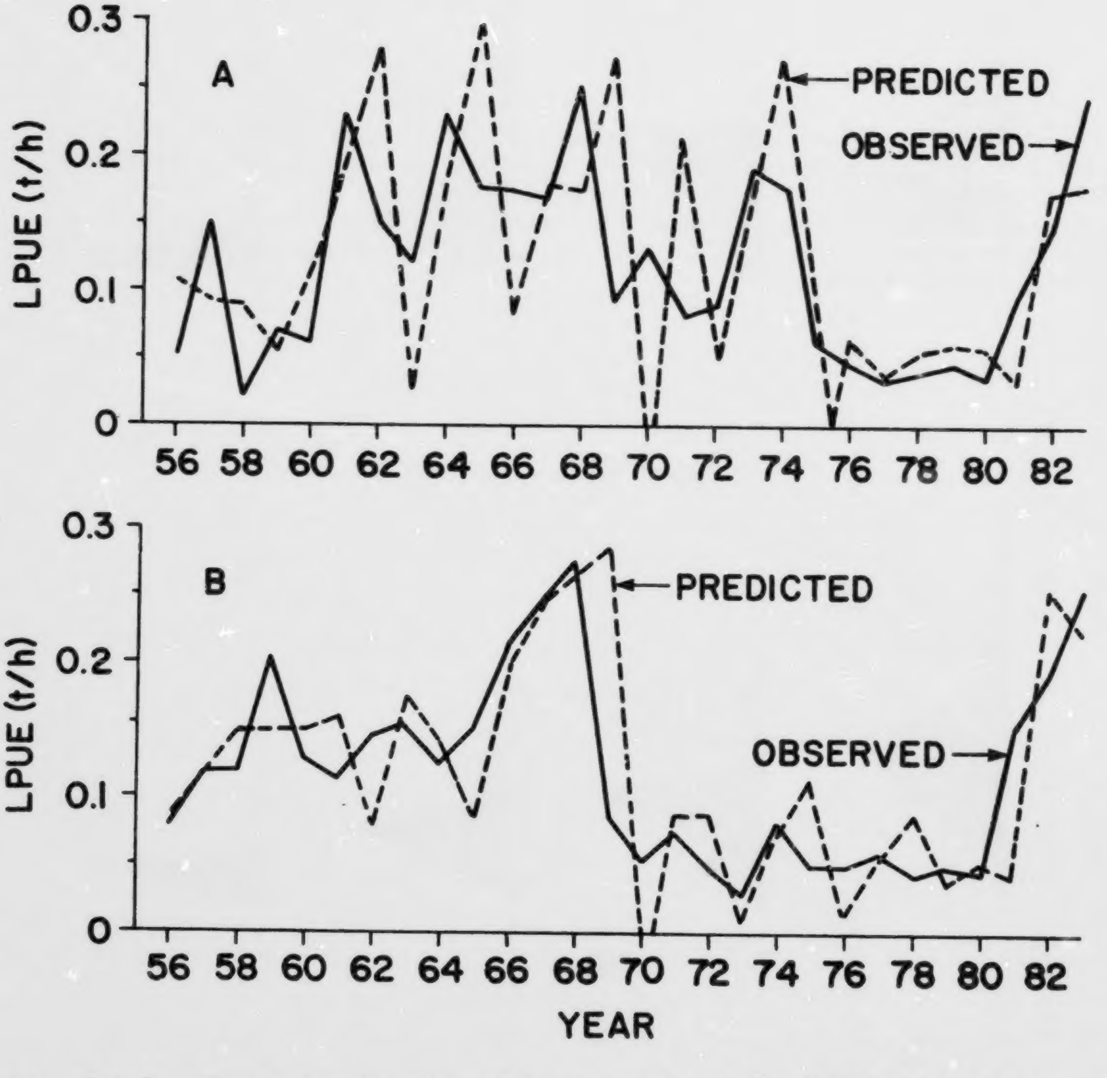

Fig. 2.4.3. Observed and predicted LPUE from Deriso's (1980) delay-difference population model for lingcod in A) Area 5A and B) Area 5B, 1956-83.

extreme ranges in natural mortality (M = 0.2; 0.4), MSY for Area 5A varied very little (451-453 t/yr). The range in MSY for Area 5B was 639 t/yr (M = 0.2) to 733 t/yr (M = 0.4).

As found in other offshore areas, commercial production is highly dependent on periodic surges in recruitment. The most recent surge in recruitment in Queen Charlotte Sound occurred as part of a coast-wide surge in the strengths of the 1976-78 year-classes. These year-classes emerged as a prominent length mode in length-frequencies collected from commercial fisheries during 1980-83 (Fig. 2.4.4).

2.4.4. Recommendations

Stocks in Queen Charlotte Sound are currently at high levels. The present analysis suggests recruitment is dependent on environmental factors rather than stock size. At present there is no evidence to indicate the dynamics of lingcod stocks in Queen Charlotte Sound are adversely influenced by fishing pressure. Therefore we are not making any recommendation for Queen Charlotte Island stocks.

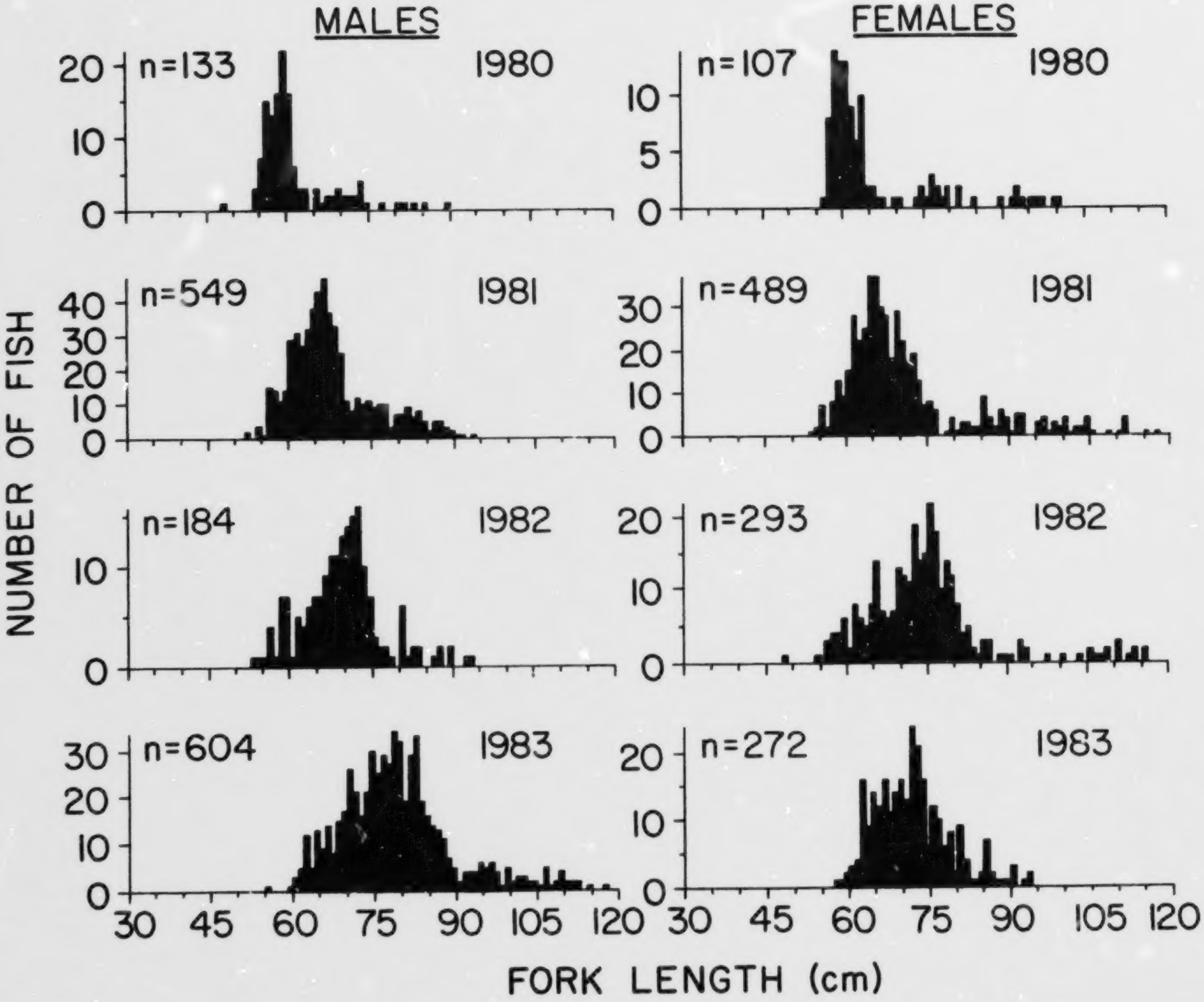

Fig. 2.4.4. Length-frequency histograms of lingcod in commercial trawl samples from Queen Charlotte Sound, 1980-83.

3. PACIFIC COD

by S. J. Westrheim and R. P. Foucher

General introduction

Pacific cod (Gadus macrocephalus) is the long-time mainstay of the domestic on-bottom trawl fishery. In Canadian waters, it is close to the southern limit of its range as a commercial resource. In contrast to its arctic and sub-arctic counterparts, growth is rapid and life is short. Recruitment begins at age 2, most are mature at age 3, and few survive to age 7. Recruitment fluctuates substantially, and quasi-cyclically, among year classes, and these fluctuations are reflected in the Canada-U.S. landings (Fig. 3.1).

Among regions, cod production is greatest in Hecate Strait, and negligible off the west coast of the Queen Charlotte Islands. Cod production has been declining in all regions in recent years, and this decline probably reflects the historic quasi-cyclic, and as yet unpredictable, fluctuations in abundance.

3.1 Coastwide

Pacific cod were not treated as a coastwide stock.

3.2 Georgia Strait and vicinity

3.2.1 Introduction

Detailed analysis of Pacific cod stock(s) in Area 4B awaits the standardization of trawling effort and final checking of age-frequency data. Neither aspect will be completed prior to spring 1985. For this report, only annual landings are available for review.

During 1956-83, Pacific cod landings from Area 4B have averaged 788 t/annum, with a range of 377 (1961) to 1,273 t (1980) (Fig. 3.2.1). Except for 1978-80, the annual landings oscillated without trend. The anomalous landings of 1978-80 were caused by an as yet unexplained temporary concentration of cod in Minor Statistical Area 19 (Juan de Fuca Strait) during August-December.

Numerous Canadian and U. S. tagging experiments (Gosho 1976; Bargmann 1980; Westrheim 1982) have demonstrated the interrelationship between Area 4B (Canada) and the adjacent "inside" Area 4A (United States). Annual landings also exhibit similar magnitudes and trends.

3.2.2 Recommendation

Available evidence suggests that no change is required in current regulations involving cod in Area 4B. There is no quota in effect.

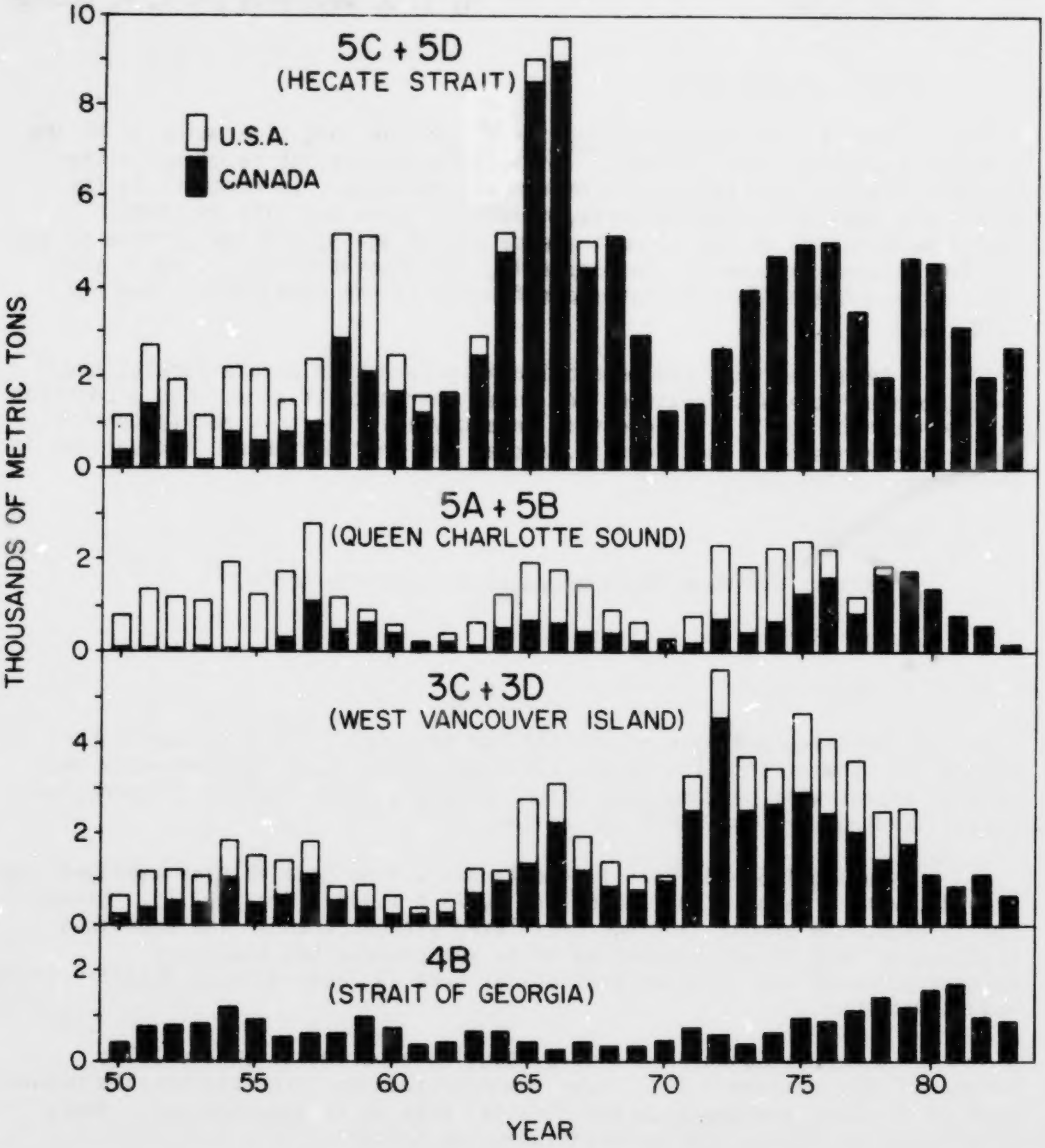

Fig. 3.1. Canada-U.S. landings (t) of Pacific cod, by region, 1950-83.

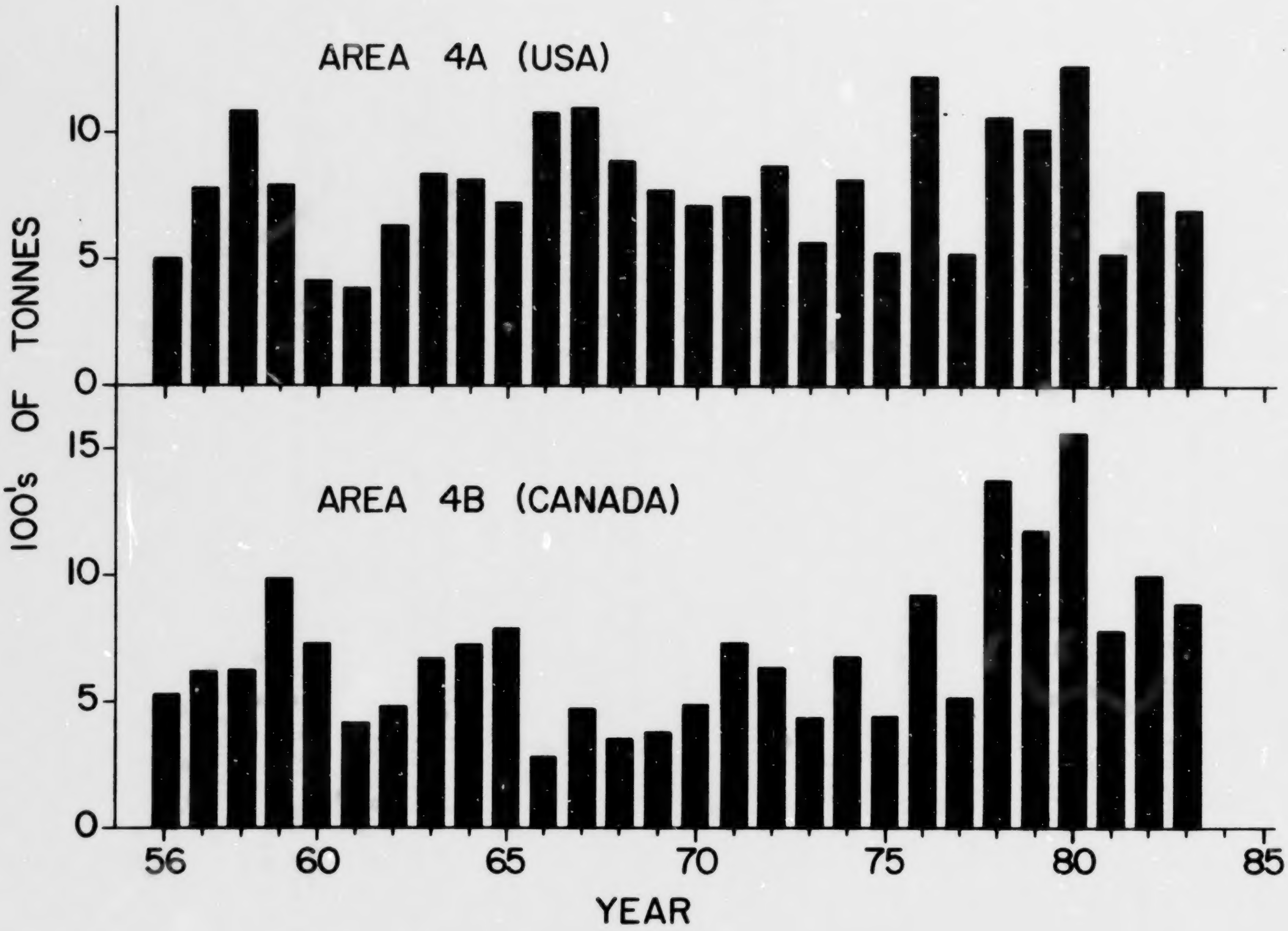

Fig. 3.2.1. Landings (t) of Pacific cod from Puget Sound and adjacent waters (Area 4A), and Georgia Strait and adjacent waters (Area 4B), January-December 1956-83.

3.3. WEST COAST OF VANCOUVER ISLAND

3.3.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery off West Vancouver Island. Its two important co-habitants are lingcod and petrale sole. Annual landings of the three species oscillate non-synchronously (Fig. 3.3.1). At times a reciprocal relationship is apparent for cod landings versus lingcod and petrale sole, e.g., 1959-60 (small cod landings/large landings of lingcod and petrale sole), and 1970-72 (large cod landings/small landings of lingcod). Although the subsequent stock assessments in this report are addressed to individual species, the multi-species aspect is recognized, and future analyses will incorporate this aspect.

Off the west coast of Vancouver Island, Area 3C (Canadian portion) (Fig. 1) produces approximately 90% of the Pacific cod, and Area 3D, 10%. Within Area 3C, principal trawling grounds are Amphitrite Bank (49%), Big Bank (26%), and Swiftsure Bank (12%) (Foucher and Westrheim 1984) (Fig. 3.3.2). Amphitrite Bank is a major spawning ground for cod, and 77% of its production occurs during January-March. Big Bank and Swiftsure Bank are feeding areas for cod, and production occurs primarily during April-September--80% and 88%, respectively. The trawl fishery on spawning cod began about 1966, and assumed considerable importance after 1971.

3.3.2. Landing statistics

Landing statistics are based on Foucher (1984) for detailed records by ground. Effort was allotted in the mixed-species fisheries using the method of Westrheim (1983), and standardized according to the method of Westrheim and Foucher (in preparation). Essentially, the standardization was a linear function utilizing vessel horsepower as the single factor in the regression. Representative LPUEs for the region were derived from Canadian records for Big Bank, April-September.

For all off-shore regions, the cod "year" is April-March, which best describes the activities of the cod and their recruitment. Recruitment begins with age-2 cod in April, and generally concludes the following January-March when these cod spawn for the first time at age 3[1].

Records prior to 1960 are questionable, because of the dissimilarity between the Canadian and U.S. trawl fleets, and the absence of detailed records of the U.S. fleet.

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[1] Arbitrary "birthday" for all fish aged at the Pacific Biological Station is January 1 (Chilton & Beamish 1982).

Effort. During 1960-84, effort fluctuated substantially, but without trend (Fig. 3.3.3; Table 3.3.1). Zeniths occurred in 1961-62 (30,471 h), 1967-68 (24,795 h), 1975-76 (22,306 h), and 1981-82 (24,902 h). Corresponding nadirs occurred in 1964-65 (7,011 h), 1971-72 (10,344 h), and 1979-80 (7,031 h). These oscillations were not synchronous with landings.

Landings. During 1956-84, landings also fluctuated substantially, with an upward trend through 1972-73, followed by a steady decline. Zeniths occurred in 1957-58 (1,674 t), 1966-67 (3,230 t), 1972-73 (5,681 t), 1979-80 (1,568 t), and 1981-82 (1,591 t). Corresponding nadirs occurred in 1961-62 (518 t), 1969-70 (936 t), and 1980-81 (1,163 t).

LPUE. LPUEs also fluctuated substantially, without long-term trend, but somewhat more synchronously with landings. Zeniths occurred in 1960-61 (52 kg/h), 1964-65 (284 kg/h), 1972-73 (483 kg/h), and 1979-80 (223 kg/h). Nadirs occurred in 1961-62 (17 kg/h), 1969-70 (60 kg/h), and 1977-78 (157 kg/h). The relative stability of LPUEs during 1973-79 (149-194 kg/h) may well be an anomaly brought about by effort declining proportionately to landings, due to a true decline in abundance.

Summary. Cod abundance appears to be oscillating without long-term trend, although the trend in landings suggests a relatively steady decline in abundance after 1972-73. The steady decline in landings coincides with the initiation of a substantial fishery for spawning cod on Amphitrite Bank during January-March. During 1972-77, cod landings from this area-time cell averaged 1,850 t (1,307-2,347 t) (Foucher 1984, Table 4), 45% of the annual mean production (4,079 t; 3,038-5,681 t) for the region (Area 3C + 3D). Various conservation regulations have been imposed during January-March since 1977 which have substantially reduced trawling effort and landings, in most cases.

3.3.3. Age composition

Age compositions are derived from length frequencies for Canadian cod landings using the method of Foucher and Fournier (1982).

Age-classes 2-4 predominate in the landings, and few cod landed from the west coast of Vancouver Island are older than age 7 (Table 3.3.2). Recruitment is considered complete at age 3. Year-class abundance, based on LPUE at age 2, fluctuates substantially--1.7 cod/h in 1967 to 99.3 cod/h in 1972, during 1962-83. Data prior to 1962 are questionable due to the dissimilarity of the Canadian and U.S. trawl fleets at that time, and the absence of detailed records of the catches by U.S. vessels.

Anomalies in the age compositions are evident, particularly with respect to strong (abundant) year classes, as the following example from Table 3.3.2 indicates:

Age class	Year-class LPUE (N/h) 1960	1961	1962
2	11.7	27.8	8.9
3	11.4	55.4	41.6
4	31.9	16.0	21.6
5	4.5	4.9	2.2
6	2.9	0.9	1.4
7	0.3	0.3	0.3

The relationship of LPUEs, at age 2, between the 1961 year-class and its two neighbors changes substantially such that at age 4, the 1961 year-class is the least abundant! This phenomenon can be seen for each strong year-class (or group) in Table 3.3.2. We suspect that the cause is the age-determination process.

3.3.4. Mortality rates

Mortality rates (all instantaneous) were calculated from ln LPUEs of selected age classes arrayed by year-class, rather than year, because of cod's short life span and substantial fluctuations in year-class abundance. Total mortality rate (Z) was calculated by regressing ln LPUEs for selected age classes on age--ages 3-6, 3-7, and 4-7. The slope of the regression line is an estimate of Z. Natural mortality rate (M) was calculated by regressing Z on effort[1]. The y-intercept is an estimate of M, and the slope is an estimate of the catchability coefficient (q).

Two routes were followed to obtain estimates of mortality rates. The first involved all year-classes, and unadjusted LPUEs. The second involved selected strong year-classes, and their adjusted LPUEs.

All year-classes. Estimates of Z for year-classes 1960-77 ranged from 0.41 to 1.52 -- for age-classes 3-6, 0.58-1.65 for age-classes 3-7; and 0.77-1.75 for age-classes 4-7 (Table 3.3.3). Eighty-one percent of the Z values fell within the range 0.81-1.45. Notable were the relatively high values of Z for year-classes 1975 and 1976. Following are the results of the computations for the other parameters:

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[1] Beverton and Holt (1957) define $Z=M+qf$, where q is the catchability coefficient, and f is fishing intensity (effort/unit area). Hence effort is a satisfactory substitute for fishing intensity, if fishing area remains constant.

Parameter	Age-classes 3-6	3-7	4-7
Z	1.08	1.14	1.26
M	0.25	1.07	1.12
F	0.83	0.07	0.14
q	1.39×10^{-5}	9.17×10^{-7}	2.31×10^{-7}
r[a]	0.414	0.0313	0.0768

[a] For regression of Z on effort.

Estimates of Z ranged from 1.08 to 1.26 and might be reasonable. However estimates of M (0.25,1.07, and 1.12) were not deemed to be reasonable. These were not carried forward in subsequent analyses.

Strong year-classes. For year-classes 1961, 1965-66, 1969-70, and 1972-73, the relationship between their LPUEs at age 2 and those of the two adjacent year-classes, at the same age, was applied to subsequent age-classes 3-7 (Table 3.3.4). For example, LPUE for the 1961 year-class was 27.8 cod/h compared to 11.7 for year-class 1960, and 8.9 for year-class 1962. The corresponding summed LPUEs for age-classes 3-7 were each multiplied by 0.574 to produce an estimate of the "adjusted" LPUE for the 1961 year class. These adjustments presumably corrected for the apparent age-determination anomalies. That is, we are assuming that the relationship of the three cohorts, observed at age 2, is true, and remains constant at least through age 7. Estimates of the appropriate parameters are contained in Table 3.3.5. "Best" estimate of M was considered to be 0.58 (ages 3-6), which produced a Z of 1.11 and F of 0.53. Correlation was good (r=0.719), and $q=8.74 \times 10^{-6}$. If we assume that q contains no bias, then estimates of $\hat{F}$ (=qE) among the strong year-classes ranged from 0.44 (1965-66) to 0.64 (1969-70), and estimates of $\hat{M}$ ranged from 0.48 (1972-73) to 0.66 (1965-66). Similar computations for the individual year classes (1960-77) in Table 3.3.6, yield estimates of M ranging from 0.19 to 1.44, but 8 of the 17 estimates (excluding that for year-class 1966 of -0.02) ranged from 0.41-0.67. The large removals during the winter fisheries of 1972-77 are not reflected in larger values of Z (for the 1969-72 year classes), nor in larger values of F (=qE). In the latter case, total annual effort was probably underestimated.

3.3.5 Virtual population analysis (VPA)

A virtual population analysis (Gulland 1969) was undertaken utilizing the mortality rates derived from selected strong year-classes, over age classes 3-6-- F at age 7=0.53; M=0.58, a constant (see Section 3.3.4). Estimated numbers present at age 2 ranged from 1.0 million in 1960 to 6.3 million in 1971 (Table 3.3.7). Mean values of F for fully recruited age classes ranged from 0.41 (age 3) to 0.70 (age 5) (Table 3.3.8).

Summary. The estimates of exploitation rate seem low, but are probably due to the large component of natural mortality. However, the generally high values during 1971-77 coincide with the new winter fishery on spawning cod. Exploitation rate continued high during a 60% decrease in stock size -- from 10.7 million in 1971 to 4.3 million in 1977.

3.3.6 Abundance for 1984

The abundance index for Pacific cod off west Vancouver Island (Areas 3C + 3D) is the LPUE from Big Bank (Area 3C) during April-September. The provisional index value (based on -95% complete landing records) for 1984 is 35 kg/h, the lowest value since 1964 (25 kg/h) (Table 3.3.1).

No length frequency samples were obtained for Area 3C during April-October 1984, and hence no age composition data are available.

An extrapolation of the LPUE/VPA relationship suggests that the cod stock in Areas 3C + 3D may be at a record low of only 824,000 individuals, age 2 and older. The computations are as follows:

$$\hat{N}_{84} = (\overline{N}_{77-79})(\text{LPUE}_{84})(\overline{\text{LPUE}}_{77-79}),$$

where $\hat{N}_{84}$ = estimated numbers (10^3 > age 2) in stock during April-March 1984-85 = $\underline{824}$

$\overline{N}_{77-79}$ = mean numbers (10^3 > age 2) in stock during April-March 1977-79 = $\underline{3,671}$

LPUE_{84} = kg/h during April-September 1984 = $\underline{35}$

LPUE_{77-79} = mean kg/h during April-September 1977-79 = $\underline{156}$.

The lowest previous nadir in stock size was 2,240,000 during 1959-63.

3.3.7 Conclusions and Recommendations

Available evidence strongly suggests that the cod stock off west Vancouver Island is at an extremely low level of abundance. Therefore, a very conservative management philosophy should prevail.

Three alternative actions are proposed--conservative, intermediate, and optimistic. The conservative proposal is to close Area 3C (containing the principal spawning ground) to trawling at $\leq$ 100 fath, during January-March, assuming that recruitment overfishing is imminent or has already occurred. The intermediate proposal is to allow one week of trawling (for the same area) in the middle of January, February, and March, assuming recruitment overfishing is not quite so imminent. The optimistic proposal is to apply no regulations, assuming that recruitment overfishing is not likely.

Annual exploitation rates (nos. landed/nos. present) for age-classes 3-7 fluctuated substantially, and quasi-cyclically, among years. Values ranged from 0.10 (1963) to 0.43 (1966), with a mean of 0.27 (Table 3.3.9). The 1966 zenith coincided with a zenith in landings and LPUEs (Fig. 3.3.2). Subsequently, LPUEs declined substantially in both cases. However, no such response occurred following the relatively large exploitation rates for 1975 (0.22), 1976 (0.24), or 1977 (0.23).

A second estimate of exploitation rate employs the formula of Ricker (1975) -- $\mu = AF/Z$, where $A = 1\text{-}e^{-Z}$. For $F = 0.53$, and $Z = 1.11$, $\mu = 0.32$.

A second VPA was undertaken in which terminal F at age 7 was allowed to vary with effort at age 7:

$$\hat{F}_7 = \bar{q}_7\bar{E}_7$$

where $\hat{F}_7$ = estimated terminal F at age 7

$\bar{q}_7$ = mean catchability coefficient at age 7

and $\bar{E}_7$ = mean effort at age 7.

The mean catchability coefficient ($\bar{q}_7$) at age 7 was calculated by dividing mean F at age 7 by mean effort at age 7. Resulting estimates of numbers present at age 2 varied by less than 2% from those derived from the first VPA, using a constant value of F.

Table 3.3.1. Canada-U.S. landing statistics for Pacific cod from off West Vancouver Island (Areas 3C + 3D), April-March, 1956-84.

Year	Equivalent effort (h)	Landings (t)	LPUE[a] (kg/h)
1956-57	12,073	1,485	123
57-58	15,500	1,674	108
58-59	9,500	798	84
59-60	25,722	926	36
1960-61	10,865	565	52
61-62	30,471	518	17
62-63	24,324	827	34
63-64	12,548	1,167	93
64-65	7,011	1,991	284
1965-66	13,457	2,678	199
66-67	15,381	3,230	210
67-68	24,795	1,810	73
68-69	13,883	1,069	77
69-70	15,600	936	60
1970-71	11,887	1,581	133
71-72	10,344	4,903	474
72-73	11,762	5,681	483
73-74	15,906	3,038	191
74-75	19,995	3,879	194
1975-76	22,306	3,502	157
76-77	19,022	3,424	180
77-78	16,859	2,512	149
78-79	8,286	1,392	168
79-80	7,031	1,568	223
1980-81	9,304	1,163	125
81-82	24,902	1,519	61
82-83	16,889	608	36
83-84	12,697	838	66

[a] Big Bank (Area 3C), Apr-Sep.

Table 3.3.2. Canada-U.S. landings(t) of Pacific cod, standardized equivalent effort(h) and number/h by age, from the west coast of Vancouver Island (Areas 3C + 3D) during April-March 1956-83.

Year[a]	C-U.S. Land (t)	C-U.S. Eff (h)	Age									
			1	2	3	4	5	6	7	8	9	10
1956	1485	12076	-	6.4	15.7	15.2	6.8	0.6	0.4	0.2	-	-
1957	1674	15502	-	12.6	15.5	8.4	4.9	1.2	0.2	0.1	0.1	-
1958	798	9500	-	1.3	26.4	4.7	2.0	0.4	0.2	-	-	-
1959	926	25723	-	1.1	5.1	4.5	1.0	0.1	0.1	-	-	-
1960	615	11828	-	0.4	11.4	6.0	1.8	0.3	-	-	-	-
1961	518	30472	-	0.5	1.2	3.1	1.4	0.1	-	-	-	-
1962	827	24327	-	11.7	3.3	1.7	0.6	0.1	0.1	-	-	-
1963	1167	12548	-	27.8	11.4	4.8	1.1	0.1	0.1	-	-	-
1964	1991	7011	-	8.9	55.4	31.9	12.5	4.6	0.8	0.2	-	-
1965	2678	13458	-	16.0	41.6	16.0	4.5	0.8	0.3	0.1	-	-
1966	3230	15397	-	13.9	42.1	21.6	4.9	2.9	0.4	0.1	-	-
1967	1810	24796	-	1.7	14.0	7.2	2.2	0.9	0.3	0.1	-	-
1968	1069	13881	-	3.8	14.5	5.6	2.2	1.4	0.3	0.2	-	-
1969	936	15603	-	6.2	9.6	6.2	1.9	0.4	0.3	0.1	-	-
1970	1581	11887	-	22.2	26.1	9.2	3.2	0.7	0.4	0.2	-	-
1971	4903	10345	0.8	83.2	89.1	23.8	7.0	1.5	0.6	0.5	-	-
1972	5681	11760	0.9	99.3	67.0	29.9	9.0	2.7	0.6	0.2	-	-
1973	3038	15905	-	8.8	22.4	23.2	8.3	2.6	1.0	0.2	0.1	-
1974	3879	19995	-	24.8	30.6	15.6	6.8	2.7	0.5	0.4	-	-
1975	3502	22307	-	15.0	32.0	13.9	4.9	1.0	0.3	0.1	-	-
1976	3424	19023	-	10.7	31.5	20.3	5.5	1.5	0.5	0.2	-	-
1977	2512	16859	-	11.8	24.4	14.5	5.6	1.1	0.9	0.2	0.1	-
1978	1392	8287	-	6.1	29.7	13.4	4.2	0.9	0.6	0.1	0.1	-
1979	1568	7027	0.1	31.9	36.2	18.6	7.7	1.6	0.2	0.2	-	-
1980	1163	9257	0.6	22.4	14.4	10.7	5.1	2.0	0.1	0.0	0.1	-
1981	1519	24901	0.2	3.3	15.7	4.9	1.7	0.8	0.4	0.1	-	-
1982	608	16890	-	5.0	7.5	3.3	0.6	0.1	0.1	-	-	-
1983	838	12698	-	12.5	9.0	8.1	2.5	1.1	0.1	-	-	-

[a] 1956=1956-57, etc.

Table 3.3.3. Cumulative LPUE (ΣLPUE), cumulative effort (ΣE) and estimated Z, by year-class, over selected age-classes of Pacific cod landed from grounds off west Vancouver Island (Areas 3C + 3D).

	Ages 3-6			Ages 3-7			Ages 4-7		
Year-class	ΣLPUE (N/h)	ΣE (10^3h)	Z	ΣLPUE (N/h)	ΣE (10^3h)	Z	ΣLPUE (N/h)	ΣE (10^3h)	Z
1960	50.7	48.4	.61	51.0	73.2	.97	39.6	60.7	1.44
61	77.2	60.7	1.35	77.5	74.5	1.33	22.1	67.5	1.36
62	66.8	67.5	1.25	67.1	83.1	1.26	25.5	69.7	1.33
63	51.9	69.7	1.52	52.3	81.6	1.22	10.2	66.2	1.04
64	22.2	66.2	1.01	22.8	76.5	.84	8.8	51.7	0.77
1965	25.4	51.7	.75	26.0	63.5	.78	11.5	49.6	0.78
66	28.5	49.6	.41	29.5	65.5	.58	19.9	49.9	0.76
67	61.5	49.9	.79	62.0	69.9	1.01	35.9	58.0	1.28
68	130.0	58.0	1.18	130.3	80.3	1.38	41.2	70.0	1.49
69	98.0	70.0	1.38	98.5	89.0	1.29	31.5	77.2	1.34
1970	44.4	77.2	.93	45.3	94.1	.88	22.9	78.2	0.97
71	51.1	78.2	1.09	51.7	86.5	1.04	21.1	66.5	1.10
72	58.8	66.5	1.20	59.0	73.5	1.33	27.0	51.2	1.57
73	51.8	51.2	1.02	51.9	60.5	1.37	20.4	41.4	1.59
74	47.5	41.4	.81	47.9	66.3	1.01	23.5	49.5	1.19
1975	54.2	49.5	1.21	54.3	66.4	1.45	24.6	58.1	1.75
76	48.7	58.1	1.95	48.8	70.8	1.65	12.6	63.7	1.69
77	21.0	63.7	.98	-	-	-	-	-	-

Table 3.3.4. Computation of adjusted LPUEs (N/h) for selected strong year-classes of Pacific cod from grounds off west Vancouver Island.

Age (y)		Year-class				Age (y)		Year-class			
		1960	1961	1962	Total			1962	1963-64	1965	Total
2	N/h	11.7	27.8	8.9	48.4	2	N/h	8.9	15.0	1.7	25.6
	%	24.2	57.4	18.4	100.0		%	34.8	58.6	6.6	100.0
3	N/h		62.2		108.4	3	N/h		49.3		84.2
4	N/h		39.9		69.5	4	N/h		20.0		34.2
5	N/h		6.7		11.6	5	N/h		4.4		7.5
6	N/h		3.0		5.2	6	N/h		2.1		3.5
7	N/h		0.5		0.9	7	N/h		0.8		1.4

Age (y)		Year-class				Age (y)		Year-class			
		1968	1969-70	1971	Total			1971	1972-73	1974	Total
2	N/h	22.2	91.3	8.8	122.3	2	N/h	8.8	19.9	10.7	39.4
	%	18.2	74.6	7.2	100.0		%	22.3	50.5	27.2	100.0
3	N/h		122.6		164.4	3	N/h		43.8		86.8
4	N/h		47.1		63.2	4	N/h		22.6		44.7
5	N/h		14.7		19.7	5	N/h		9.1		18.1
6	N/h		3.8		5.1	6	N/h		2.2		4.4
7	N/h		1.2		1.6	7	N/h		0.6		1.2

Table 3.3.5. Computation of M and F for selected strong year-classes of Pacific cod from grounds off west Vancouver Island.

Year	Ages 3-6		Ages 3-7		Ages 4-7		Ages 3-6	
class	ΣE	Z	ΣE	Z	ΣE	Z	F	M
1961	60.7	1.09	74.6	1.22	67.6	1.39	0.53	0.56
1965-66	50.6	1.10	64.4	1.05	49.7	1.04	0.44	0.66
1969-70	73.7	1.27	91.6	1.17	77.8	1.12	0.64	0.63
1972-73	58.9	0.99	67.0	1.09	46.3	1.23	0.51	0.48
M	0.58		0.83		1.08			
q	8.74×10^{-6}		4.00×10^{-6}		1.89×10^{-6}			
r	0.719		0.638		0.186			
Z	1.11		1.13		1.20			
F	0.53		0.50		0.07			

Table 3.3.6. Computation of F and M for year-classes 1960-77 of Pacific cod from grounds off west Vancouver Island.

Year-class	Ages 3-6			Ages 3-7		
	Z	F[a]	M	Z	F[b]	M
1960	0.61	0.42	0.19	0.97	0.29	0.68
61	1.35	0.53	0.82	1.33	0.30	1.03
62	1.25	0.59	0.66	1.26	0.33	0.87
63	1.52	0.61	0.91	1.22	0.33	0.89
64	1.01	0.58	0.43	0.84	0.31	0.53
1965	0.75	0.45	0.30	0.78	0.25	0.53
66	0.41	0.43	(-.02)	0.58	0.26	0.32
67	0.79	0.44	0.35	1.01	0.28	0.73
68	1.18	0.51	0.67	1.38	0.32	1.06
69	1.38	0.61	0.77	1.29	0.36	0.93
1970	0.93	0.67	0.26	0.88	0.38	0.50
71	1.09	0.68	0.41	1.04	0.35	0.69
72	1.20	0.58	0.62	1.33	0.29	1.04
73	1.02	0.45	0.57	1.37	0.24	1.13
74	0.81	0.36	0.45	1.01	0.27	0.74
1975	1.21	0.43	0.78	1.45	0.27	1.18
76	1.95	0.51	1.44	1.65	0.28	1.37
77	0.98	0.56	0.42	-	-	-

[a] $F = qE = 8.74 \times 10^{-6} (\Sigma E)$

[b] $F = qE = 4.00 \times 10^{-6} (\Sigma E)$

Table 3.3.7. VPA-based estimates of numbers-at-age (thousands) in the Pacific cod stock off the west coast of Vancouver Island (Areas 3C + 3D), for age classes 2-7, April-March 1956-84. (Parameters based on strong year classes: M=0.58; F at age 7=0.53.)

Year[a]	Age					
	2	3	4	5	6	7
1956	1153	-	-	-	-	-
1957	1557	590	-	-	-	-
1958	1033	732	159	-	-	-
1959	1161	571	232	57	-	-
1960	968	631	224	48	13	-
1961	1620	540	255	74	12	5
1962	3055	895	276	75	12	4
1963	3309	1504	443	125	32	4
1964	3571	1594	738	204	60	17
1965	3065	1957	607	251	52	11
1966	2063	1555	694	186	96	21
1967	1839	1001	406	155	50	22
1968	2730	1000	310	100	48	13
1969	3704	1484	413	118	34	13
1970	5889	1996	720	161	44	15
1971	6322	3091	890	323	62	19
1972	5619	2907	1071	321	127	24
1973	4176	2303	1052	348	104	49
1974	4706	2231	1027	326	100	29
1975	3226	2266	804	352	85	18
1976	2874	1565	753	228	118	32
1977	2103	1458	449	150	53	46
1978	1416	1031	521	80	18	17
1979	-	756	397	210	20	5
1980	-	-	240	129	78	3
1981	-	-	-	63	38	30
1982	-	-	-	-	6	7
1983	-	-	-	-	-	2

[a] 1956=1956-57, etc.

Table 3.3.8. VPA-based estimates of F-at-age for the Pacific cod stock off the west coast of Vancouver Island (Areas 3C + 3D), for age classes 2-7, April-March 1956-84. (Parameters based on strong year-classes: M=0.58; F at age 7=0.53.)

Year[a]	Age					
	2	3	4	5	6	7
1956	0.09	-	-	-	-	-
1957	0.18	0.73	-	-	-	-
1958	0.01	0.57	0.45	-	-	-
1959	0.03	0.36	0.99	0.87	-	-
1960	0.00	0.33	0.52	0.80	0.50	-
1961	0.01	0.09	0.64	1.27	0.51	0.53
1962	0.13	0.12	0.21	0.26	0.45	0.53
1963	0.15	0.13	0.20	0.16	0.07	0.53
1964	0.02	0.39	0.50	0.79	1.11	0.53
1965	0.10	0.46	0.60	0.38	0.32	0.53
1966	0.14	0.76	0.92	0.73	0.89	0.53
1967	0.03	0.59	0.83	0.60	0.80	0.53
1968	0.03	0.31	0.39	0.50	0.73	0.53
1969	0.04	0.14	0.36	0.40	0.24	0.53
1970	0.06	0.23	0.22	0.37	0.28	0.53
1971	0.20	0.48	0.44	0.35	0.38	0.53
1972	0.31	0.44	0.55	0.55	0.38	0.53
1973	0.05	0.23	0.59	0.66	0.70	0.53
1974	0.15	0.44	0.49	0.76	1.12	0.53
1975	0.14	0.52	0.68	0.51	0.40	0.53
1976	0.10	0.67	1.04	0.87	0.38	0.53
1977	0.13	0.45	1.14	1.51	0.58	0.53
1978	0.05	0.37	0.33	0.80	0.72	0.53
1979	-	0.57	0.55	0.41	1.20	0.53
1980	-	-	0.75	0.65	0.37	0.53
1981	-	-	-	1.80	1.13	0.53
1982	-	-	-	-	0.35	0.53
1983	-	-	-	-	-	0.53
Mean[b]	0.09	0.41	0.58	0.70	0.59	0.53
C.V.	0.81	0.47	0.45	0.56	0.54	-

[a] 1956=1956-57, etc.

[b] 1954-76 year-classes.

Table 3.3.9. VPA-based estimates of annual exploitation rates for the Pacific cod stock off the west coast of Vancouver Island (Areas 3C + 3D), for age classes 3-7, April-March 1961-79. (Strong year-classes: numbers in stock from Table 3.3.7.)

Year[a]	No. in stock	No. landed	Exploitation rate
1961	886	178	0.20
1962	1263	139	0.11
1963	2109	221	0.10
1964	2612	738	0.28
1965	2877	849	0.30
1966	2553	1108	0.43
1967	1634	611	0.37
1968	1470	332	0.23
1969	2061	286	0.14
1970	2936	471	0.16
1971	4384	1262	0.29
1972	4450	1284	0.29
1973	3854	913	0.24
1974	3713	1123	0.30
1975	3525	1160	0.33
1976	2696	1128	0.42
1977	2155	784	0.36
1978	1667	405	0.24

[a] 1961=1961-62, etc.

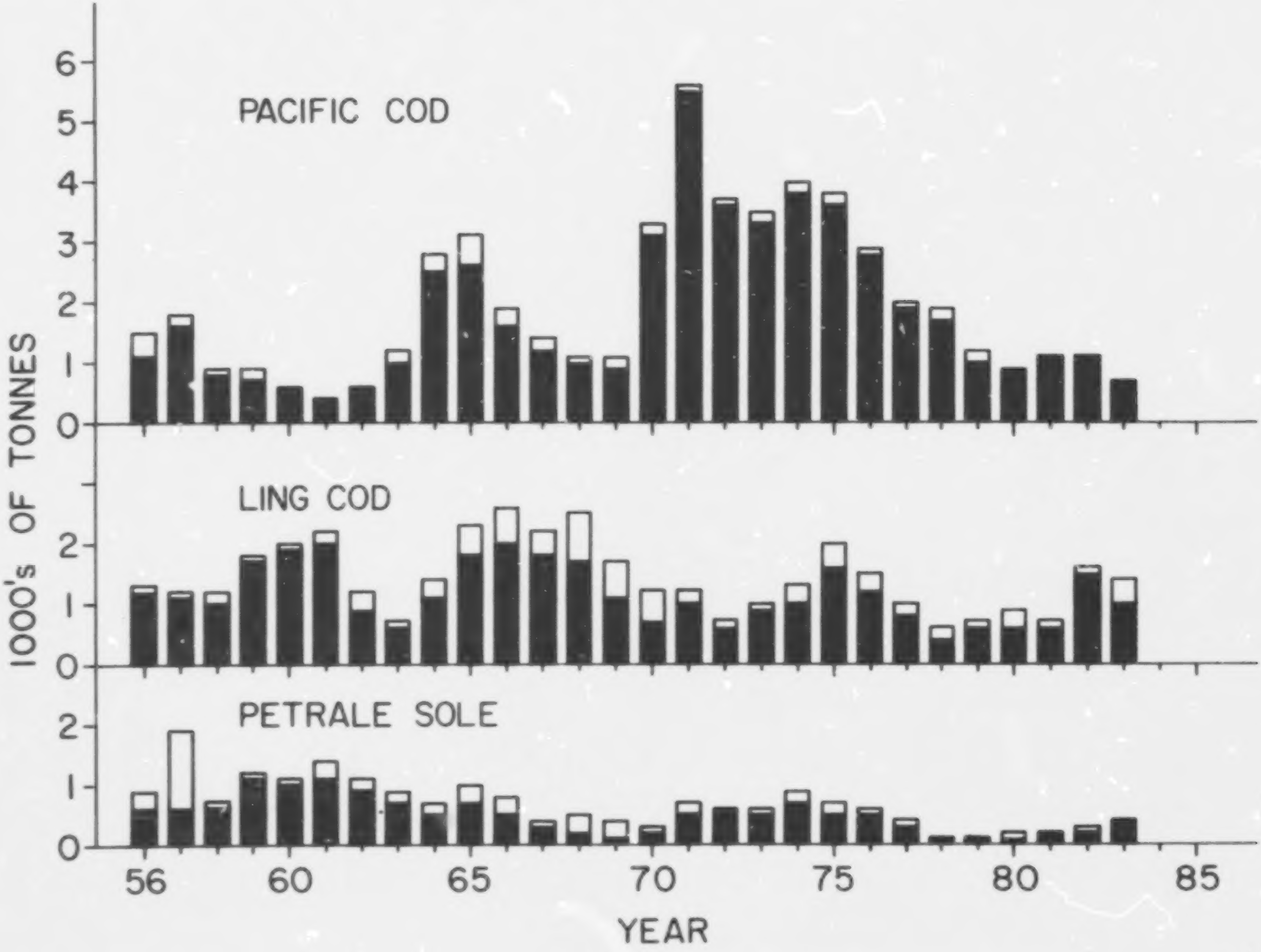


Fig. 3.3.1. Canada-U.S. landings (t) of Pacific cod, lingcod, and petrale sole from off west Vancouver Island (Areas 3C-N and 3D) January-December 1956-83. (Shaded areas = landings from Area 3C-N.)

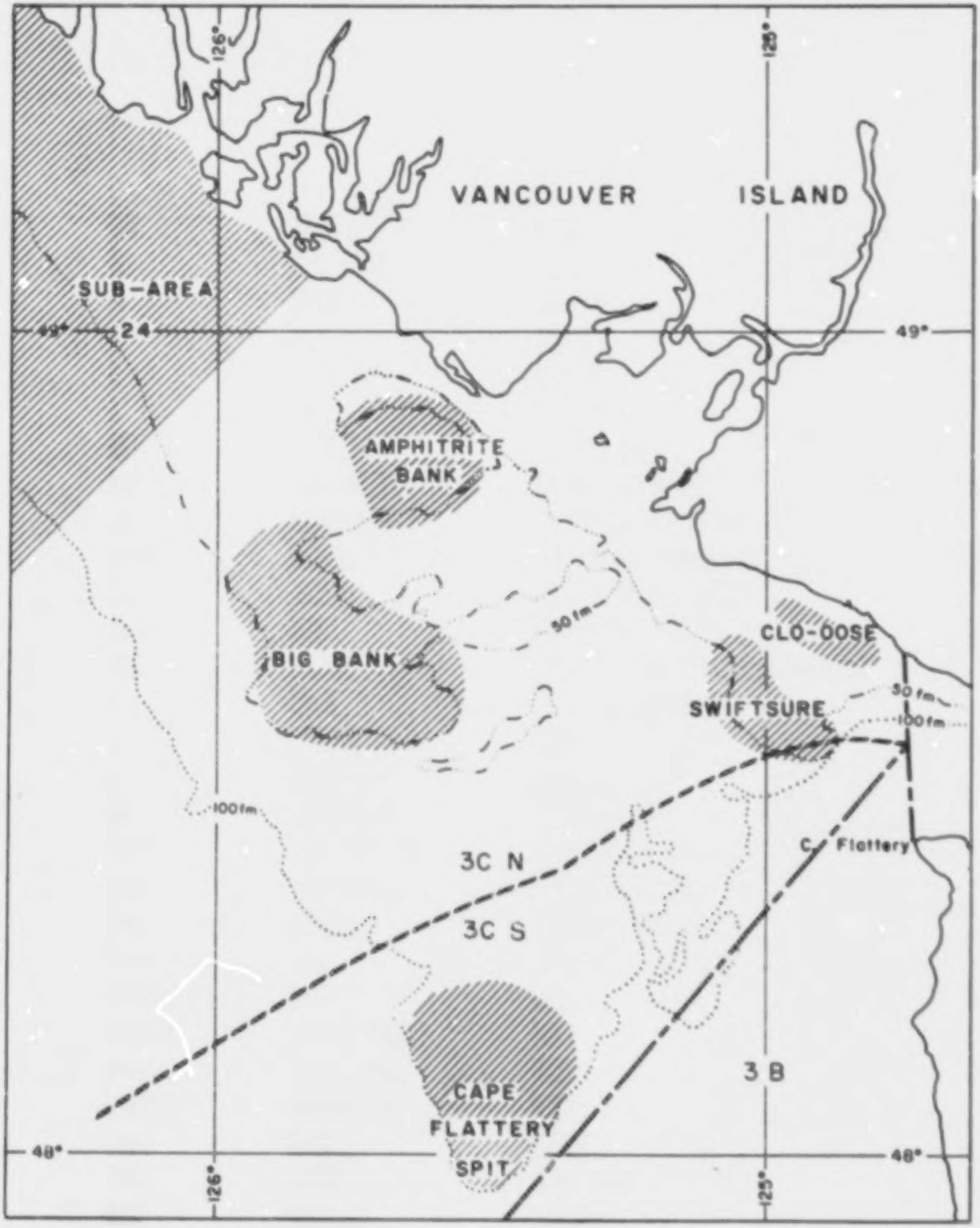

VANCOUVER ISLAND
SUB-AREA 24
49°
48°
126°
125°
AMPHITRITE BANK
BIG BANK
CLO-OOSE
SWIFTSURE
CAPE FLATTERY SPIT
50 fm
100 fm
3C N
3C S
3 B
C. Flattery

Fig. 3.3.2. Important shelf trawling grounds off southwest Vancouver Island.

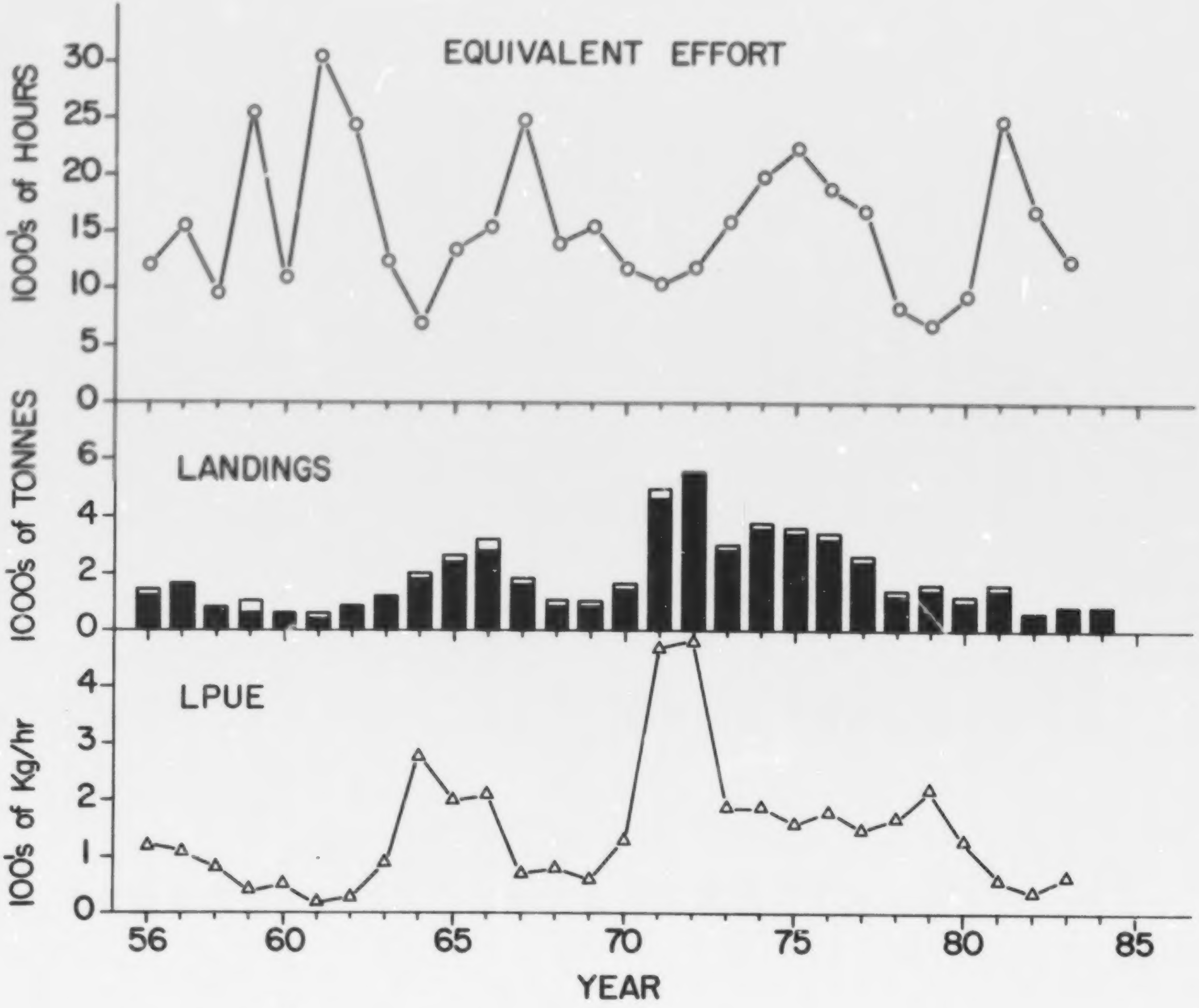


Fig. 3.3.3. Standardized Canada-U.S. landing statistics for Pacific cod from grounds off west Vancouver Island, April-March 1956-84.

3.4. QUEEN CHARLOTTE SOUND

3.4.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery in Queen Charlotte Sound. Its two important co-habitants are lingcod and rock sole. Annual landings of the three species oscillate non-synchronously (Fig. 3.4.1). At times a reciprocal relationship is apparent for cod landings versus those of its two co-habitants, e.g., 1965-68 (declining cod landings/rising lingcod landings) and 1978-80 (large cod landings/small lingcod landings). Although subsequent stock assessments in this report are addressed to individual species, the multi-species aspect is recognized, and future analyses will incorporate this aspect.

Queen Charlotte Sound encompasses two major areas--5A and 5B (Fig. 1). Two large banks dominate the shelf -- Cook Bank in Area 5A, and Goose Island Bank in Area 5B (Fig. 3.4.2). Trawling grounds are not well defined on either bank, and hence landing statistics and age compositions of landings have been compiled by major area only (Foucher and Westrheim 1984). No clear evidence is available at this time which would delineate separate stocks of cod in Areas 5A and 5B. Therefore, the current analysis is based on the combined data from the two areas.

3.4.2. Landing statistics

Landing statistics for Areas 5A and 5B were compiled in the same manner as for cod off west Vancouver Island (see Section 3.3). Representative LPUEs for Queen Charlotte Sound are the means (weighted to landings) of two area-time cells, Area 5A/April-September and Area 5B/April-September.

The cod landings from Queen Charlotte Sound are quite seasonal--87% during April-September (Foucher and Westrheim 1984). Area 5A produced 44% (82% during April-September), and Area 5B produced 56% (91% during April-September).

Records prior to 1960 are questionable, because of the relatively small Canadian production (Fig. 3.1).

Effort. Effort increased irregularly from 1958-59 (2,477 h) to 1972-73 (10,414 h), then decreased irregularly through 1983-84 (5,382 h) (Fig. 3.4.3; Table 3.4.1). The overall trend was generally independent of landings and LPUEs.

Landings. Landings continue to fluctuate quasi-cyclically without trend. Zeniths occurred in 1957-58 (2,625 t), 1965-66 (1,983 t), 1972-73 (2,416 t), 1975-76 (2,467 t), and 1979-80 (2,018 t). Corresponding nadirs occurred in 1961-62 (259 t), 1970-71 (278 t), and 1977-78 (1,316 t). Landings have declined steadily since 1979-80, and for 1983-84 were 183 t.

LPUEs. LPUEs have fluctuated similarly to landings. Principal zeniths occurred in 1957-58 (726 kg/h), 1965-66 (529 kg/h), 1975-76 (311 kg/h), and 1979-80 (305 kg/h). Corresponding nadirs occurred in 1961-62 (80 kg/h), 1970-71 (47 kg/h), and 1977-78 (162 kg/h). Zenith values have generally declined during 1956-84. LPUEs have declined steadily since 1979-80.

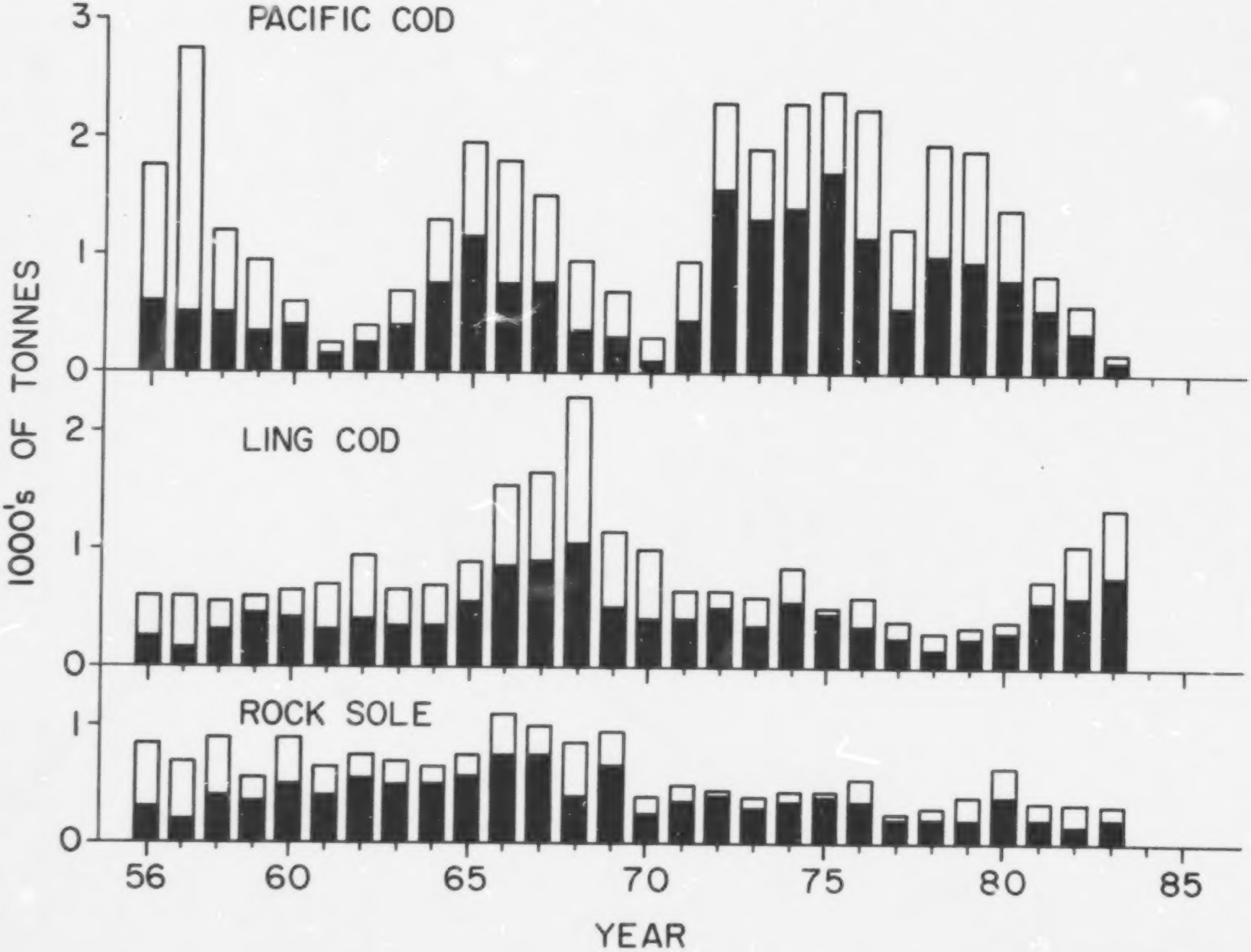


Fig. 3.4.1. Canada-U.S. landings (t) of Pacific cod, lingcod, and rock sole from Queen Charlotte Sound (Areas 5A and 5B) January-December, 1956-84. (Shaded areas = landings from Area 5B.)

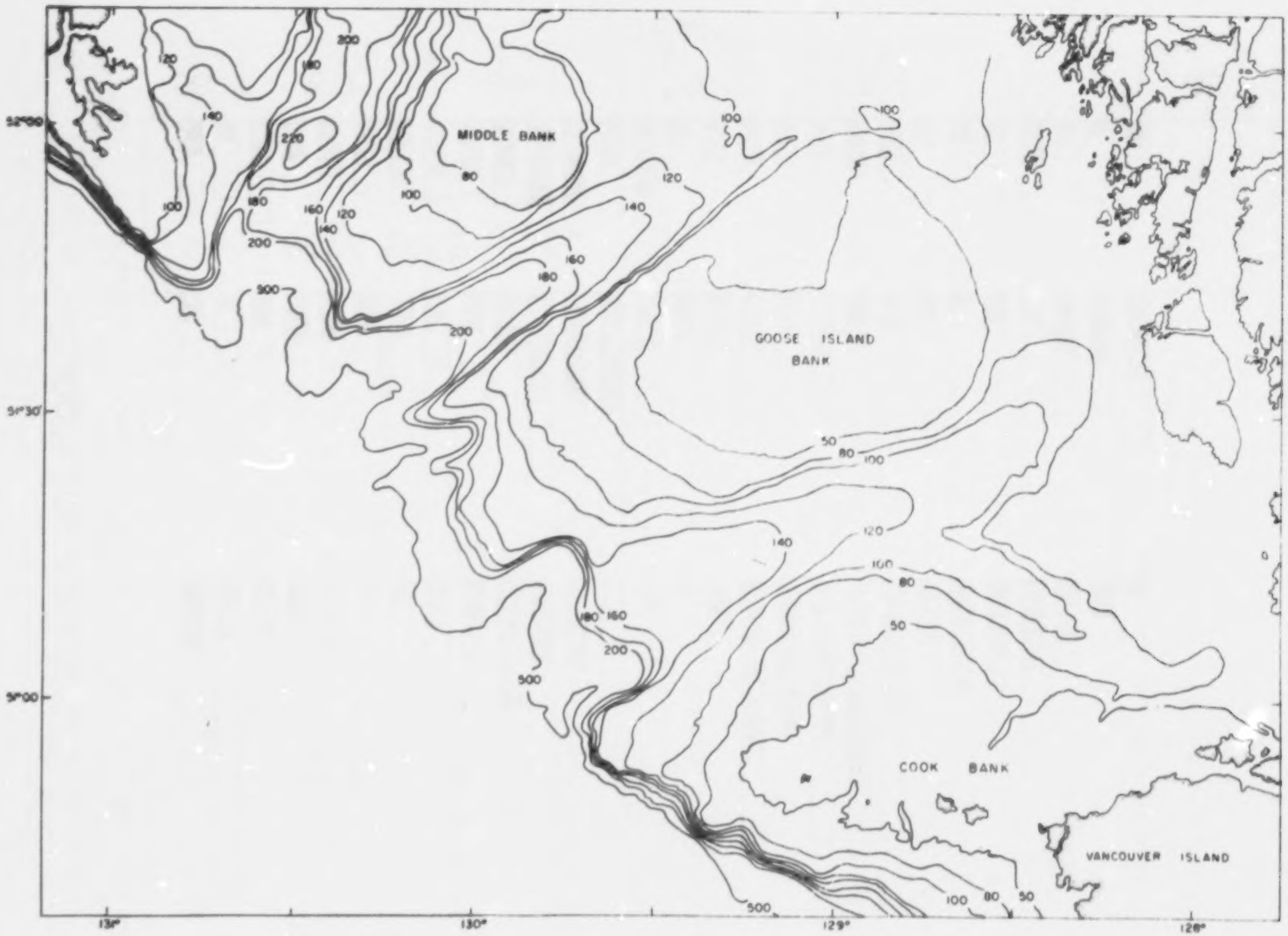

MIDDLE BANK
GOOSE ISLAND BANK
COOK BANK
VANCOUVER ISLAND
52°00'
51°30'
51°00'
131°
130°
129°
128°
50
80
100
120
140
160
180
200
220
500

Fig. 3.4.2. Important shelf trawling grounds in Queen Charlotte Sound.

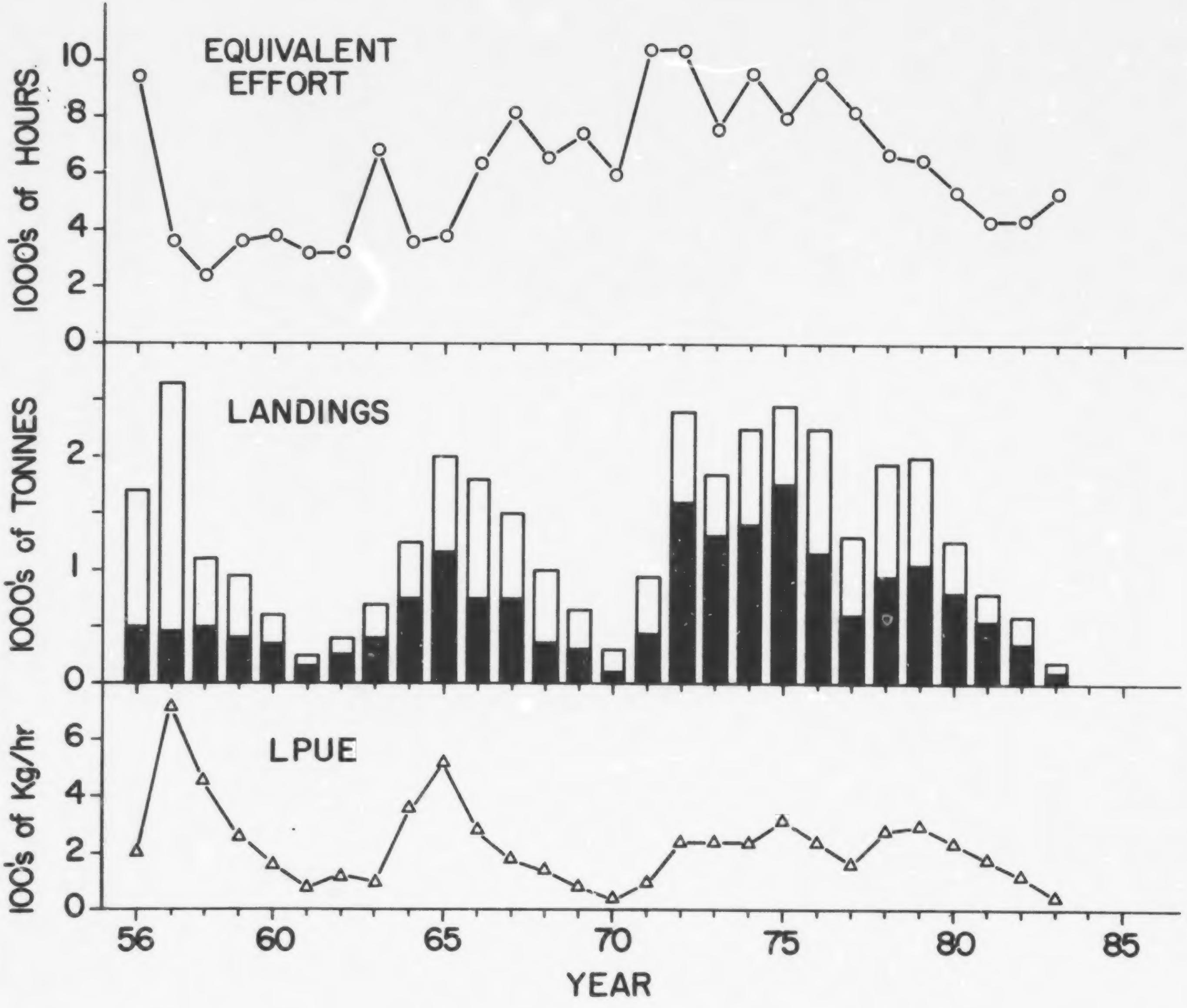


Fig. 3.4.3 Standardized Canada-U.S. landing statistics for Pacific cod from Queen Charlotte Sound, April-March 1956-84. (Shaded areas = landings from Area 5B.)

Summary. Landings and LPUEs continue to oscillate without trend, and their current declines are probably temporary, as were similar declines in the past.

3.4.3. Age composition

Age compositions are derived from length frequencies of cod landed in Canada, using the method of Foucher and Fournier (1982). Details on compilation and computation of the age composition are described by Foucher and Westrheim 1984.

Age-classes 2-4 predominate in the landings from Queen Charlotte Sound, and few cod landed are older than age 7 (Table 3.4.2). Year-class abundance, based on LPUEs at age-2, fluctuates substantially. Zeniths occurred in 1957 (193.3 cod/h), 1964 (61.5), 1972 (50.1), 1975 (72.1), and 1979 (78.1). Corresponding nadirs occurred in 1961 (2.9 cod/h), 1969 (7.2), and 1978 (30.0).

Anomalies in the age compositions (N/h) are evident, particularly with respect to strong (abundant) year-classes, as the following example from Table 3.4.2 indicates:

	Year-class LPUE (N/h)		
Age class	1961	1962	1963
2	18.3	61.5	43.8
3	46.3	66.9	27.3
4	47.3	13.5	13.5
5	9.0	5.0	6.9
6	2.6	1.6	1.3
7	0.4	1.4	0.2

The relationships at age 2 between the 1962 year-class and its two neighbours subsequently changes substantially, such that at age 4, the 1962 year-class is substantially less abundant than the 1961 year-class, and only equal to that of the 1963 year-class. This general phenomenon occurs with each strong year-class in Table 3.4.2. We suspect that the cause is a weakness in the age-determination process.

3.4.4. Mortality rates

Methods of computing mortality rates for cod from Queen Charlotte Sound were the same as those employed for cod from grounds off the west coast of Vancouver Island (see Section 3.3.4 for details).

All year-classes. Estimates of Z for year-classes 1960-77 ranged from 0.03 to 1.92 for age-classes 3-6; 0.24-1.53 for age-classes 3-7; and 0.15-1.75 for age-classes 4-7 (Table 3.4.3) -- 81% of the Z values ranged from 0.70 to

1.57. Notable was the inverse relationship between Z and cumulative effort for year-classes 1973-77 -- Z was rising while effort was falling.

Following are the results of the computations for the other parameters:

Parameter	Age classes 3-6	Age classes 3-7	Age classes 4-7
Z	1.09	1.06	1.09
M	1.65	1.63	2.05
F	-0.56	-0.57	-0.96
q	-2.00×10^{-5}	-1.60×10^{-5}	-3.23×10^{-5}
r[a]	0.300	0.406	0.501

[a] For regression of Z on effort.

Evidently, none of these estimates of M, F, or q are acceptable, the values for M being larger than Z.

Strong year-classes. For year-classes 1955, 1962, 1970, and 1973, the "adjusted" LPUEs were calculated as in Section 3.3.4 (Table 3.4.4). Resulting estimates of Z, M, and F are shown in Table 3.4.5. Estimates of Z ranged from 1.02 (ages 3-6) to 1.13 (ages 4-7), and estimates of M ranged from 0.78 (ages 4-7) to 1.04 (ages 3-6). Estimates based on ages 4-7 were deemed "reasonable"--Z = 1.13; M =0.78; F =0.35; and q =1.32×10^{-5}. Estimates of F (= qE) for the individual strong year-classes ranged from 0.18 (1955) to 0.47 (1970), while estimates of M (=Z-F) ranged from 0.68 (1973) to 0.84 (1962). Estimates of Z ranged from 0.98 (1955) to 1.26 (1970).

The reciprocal relationship between M and F for the four strong year-classes together with their modest range of Z suggests that Pacific cod are still underutilized in Queen Charlotte Sound, providing q is relatively constant. Further corroboration can be found in the current "untrawlability" of substantial portions of cod habitat on Cook and Goose Island banks (Westrheim, Harling et al. 1982; Westrheim et al. 1984) and the anomalous depths at which cod are caught by Canadian and U.S. trawlers (Westrheim and Tagart 1984).

3.4.5. Virtual population analysis

VPAs were undertaken using both fixed and variable estimates of terminal F at age 7, but with the same fixed value of M (0.78). Fixed F (0.35) was derived from the selected strong year-classes (Section 3.4.4). F values (= qE) were calculated (as in Section 3.2.5) for each year-class using a constant M and F from strong year-classes (in Section 3.4.4), and prevailing effort at age 7.

Estimated numbers at age 2. VPA using constant F (0.35) produced estimates of 1.5 (1969) to 5.8 (1971) million cod at age 2 (Table 3.4.6). VPA using variable F values produced similar estimates -- 1.3 (1969) to 6.4 (1957) million cod at age 2 (Table 3.4.7). Abundance of age-2 cod declined sharply during 1975-78 -- 4.2 million to 1.8 milliion.

F values at age. For the VPA based on constant F, mean F values for selected, fully recruited age-classes (3-7) ranged from 0.22 (age 3) to 0.44 (age 5) (Table 3.4.8). Similarly, for the VPA based on variable F, F ranged from 0.21 (age 3) to 0.42 (age 6) (Table 3.4.9).

Exploitation rates. For the constant-F VPA, exploitation rates ranged, among years, from 0.03 (1962, 1970) to 0.33 (1978), with a mean of 0.13 (Table 3.4.10). They exhibited a steady upward trend, and in the later years were approaching those estimated for the other two offshore regions. For the variable-F VPA, F estimates were similar in magnitude (0.03-0.32) and trend (Table 3.4.11).

Exploitation rate for the selected strong year-classes, as a group, was calculated with the formula $\mu = \frac{AF}{Z}$ of Ricker (1975), where $A = 1-e^{-Z}$. Using the parameters of Section 3.4.4 ($F = 0.35$; $Z = 1.13$), $\mu = (0.68)(0.35)/1.13) = \underline{0.21}$.

The steady rise in exploitation rate during 1965-78 reflects somewhat the corresponding rise in effort. Perhaps it also reflects a learning process by the Canadian trawl captains, who were, at that time, substantially increasing their share of the Canada-U.S. landings (Fig. 3.1). The absolute magnitude of the exploitation rate appears to be low, but this is caused by the large component of natural mortality rate (M) in the total mortality rate (Z = M+F).

3.4.6. Conclusions

Although exploitation rate has steadily increased during 1961-78, estimated F is low with respect to Z. Furthermore, since 1976, effort (and probably F) has declined substantially. Coupled with the results of the 1982-83 echo-sounder surveys, we can only conclude that the cod stock(s) in Queen Charlotte Sound appears to be undergoing another downward fluctuation in abundance not caused by the fishery.

An important caveat, however, is that the age compositions were calculated from length frequencies summed over quarter-years. Scheduled recalculations from length frequencies summed over months may produce somewhat less favourable results.

3.4.7. Recommendations

No regulations are recommended at this time.

Table 3.4.1. Canada-U.S. landing statistics for Pacific cod from Queen Charlotte Sound (Areas 5A+5B), April-March 1956-84.

Year	Equivalent effort (h)	Landings (t)			LPUE (kg/h)[a]		
		Total	5A	5B	Total[b]	5A	5B
1956-57	8,724	1,710	1,192	518	196	202	186
1957-58	3,616	2,625	2,156	469	726	794	351
1958-59	2,477[c]	1,122	624	498	453	565	313
1959-60	3,532	936	553	383	265	295	219
1960-61	3,850	589	236	353	153	96	187
1961-62	3,238	259	121	138	80	70	86
1962-63	3,267	392	151	241	120	58	153
1963-64	6,750	702	290	412	104	71	125
1964-65	3,535	1,255	501	754	355	255	409
1965-66	3,749	1,983	853	1,130	529	362	601
1966-67	6,377	1,811	1,068	743	284	278	290
1967-68	8,120	1,486	744	742	183	174	189
1968-69	6,622	980	625	355	148	170	109
1969-70	7,409	652	359	293	88	78	98
1970-71	5,915	278	171	107	47	71	15
1971-72	10,374	944	472	472	91	120	65
1972-73	10,414	2,416	826	1,590	232	355	177
1973-74	7,600	1,862	582	1,280	245	361	199
1974-75	9,638	2,236	832	1,404	232	276	208
1975-76	7,932	2,467	732	1,735	311	450	255
1976-77	9,597	2,265	1,122	1,143	236	256	214
1977-78	8,123	1,316	719	597	162	187	128
1978-79	6,733	1,939	992	947	288	327	249
1979-80	6,616	2,018	983	1,035	305	420	198
1980-81	5,474	1,270	545	725	232	287	188
1981-82	4,319	812	278	534	188	212	175
1982-83	4,488	579	246	333	129	145	118
1983-84	5,382	183	82	101	34	39	30

[a] April-September

[b] Mean. Weighted by April-September landings.

[c] "Corrected" value. Supersedes that reported in Foucher and Westrheim (1984)

Table 3.4.2. Canada-U.S. landings(t) of Pacific cod, standardized equivalent effort(h) and number/h by age, from Queen Charlotte Sound (Areas 5A + 5B) during April-March 1956-83.

Year[a]	C-U.S. Land (t)	C-U.S. Eff (h)	Age										
			1	2	3	4	5	6	7	8	9	10	11
1956	1710	8724	-	62.1	16.6	6.3	0.1	2.2	0.0	0.0	0.3	-	-
1957	2625	3616	2.3	193.3	83.9	31.3	7.1	2.1	0.3	0.4	0.1	-	-
1958	1122	2477	1.4	26.5	79.1	38.3	11.8	2.4	1.1	0.2	-	-	-
1959	936	3532	0.4	17.6	51.9	20.8	5.5	1.4	0.6	-	-	-	-
1960	589	3850	-	3.1	15.5	14.7	8.2	3.5	0.7	0.6	0.4	-	-
1961	259	3238	0.3	2.9	6.4	5.4	5.1	2.9	0.5	0.2	0.1	0.1	-
1962	392	3267	0.1	16.2	5.4	4.6	2.5	4.5	2.4	1.8	0.3	0.1	-
1963	702	6750	0.1	18.3	11.7	9.9	1.2	0.4	0.2	0.1	0.1	-	-
1964	1255	3535	-	61.5	46.3	14.1	9.3	4.1	1.4	-	-	-	-
1965	1983	3749	-	43.8	66.9	47.3	11.7	4.7	2.1	0.8	-	-	-
1966	1811	6377	-	47.6	27.3	13.5	9.0	3.4	0.9	0.4	0.1	0.1	-
1967	1486	8120	-	13.4	20.8	13.5	5.0	2.6	1.5	0.5	0.2	-	-
1968	980	6622	-	21.3	10.8	13.3	6.9	1.6	0.4	0.4	-	-	-
1969	652	7409	0.2	7.2	9.4	8.2	2.4	1.3	1.4	0.7	0.1	0.1	-
1970	278	5915	-	9.8	6.6	1.6	0.8	0.2	0.2	0.1	-	-	-
1971	944	10374	-	20.0	3.9	2.0	1.3	1.9	1.3	1.0	0.2	0.1	0.1
1972	2416	10414	-	50.1	21.6	7.4	0.9	3.1	0.2	2.8	0.5	0.2	0.5
1973	1862	7600	0.2	14.6	27.1	36.6	7.0	0.9	2.0	0.0	0.0	0.6	-
1974	2236	9638	-	32.5	26.6	11.6	8.8	3.6	0.3	0.6	-	-	-
1975	2467	7932	0.1	72.1	43.1	16.2	5.5	0.6	1.1	0.3	0.2	-	-
1976	2265	9597	-	46.3	42.8	9.5	4.1	2.1	0.7	1.0	0.3	0.1	-
1977	1316	8123	-	55.0	20.9	5.8	2.2	0.8	0.4	0.2	0.1	-	-
1978	1939	6733	0.7	30.0	63.1	23.3	4.2	1.7	0.6	0.1	0.0	0.2	-
1979	2018	6616	2.8	78.1	26.0	17.3	6.3	4.2	0.5	-	-	-	-
1980	1270	5474	5.3	53.4	32.6	18.0	1.4	1.0	0.5	0.0	0.0	0.1	-
1981	812	4319	0.3	45.6	19.7	7.1	2.7	1.6	0.5	0.5	0.1	0.1	0.1
1982	579	4488	2.3	27.5	23.9	4.3	1.1	0.4	0.1	-	-	-	-
1983	183	5382	-	4.1	6.8	2.0	0.3	0.1	0.1	-	-	-	-

[a] 1956=1956-57, etc.

Table 3.4.3. Cumulative LPUE (ΣLPUE), cumulative effort (ΣE), and estimated Z, by year-class, over selected age-classes of Pacific cod landed from Queen Charlotte Sound (Areas 5A+5B).

	Ages 3-6			Ages 3-7			Ages 4-7		
Year-class	ΣLPUE (N/h)	ΣE (10^3 h)	Z	ΣLPUE (N/h)	ΣE (10^3 h)	Z	ΣLPUE (N/h)	ΣE (10^3 h)	Z
1960	40.9	20.4	0.39	42.4	28.5	0.55	30.7	21.8	0.80
1961	105.2	21.8	1.03	105.6	28.4	1.24	59.3	24.9	1.56
1962	87.0	24.9	1.22	88.4	32.3	0.99	21.5	28.5	0.79
1963	49.0	28.5	0.98	49.2	34.4	1.22	21.9	28.1	1.43
1964	36.7	28.1	1.57	38.0	38.4	0.97	17.2	30.3	0.95
1965	21.7	30.3	0.75	21.9	40.7	0.94	11.1	34.1	1.03
1966	15.4	34.1	0.35	17.4	41.7	(.24)	8.0	34.3	(.15)
1967	10.4	34.3	0.68	10.7	43.9	0.70	4.1	38.0	0.47
1968	21.9	38.0	(.03)	23.0	46.0	(.33)	19.1	35.6	0.64
1969	67.6	35.6	1.22	68.3	45.2	1.10	46.7	34.8	1.46
1970	46.3	34.8	0.84	46.7	42.9	1.01	19.6	35.3	1.11
1971	47.7	35.3	1.19	48.3	42.0	1.06	21.7	32.4	1.15
1972	56.5	32.4	1.12	57.0	39.0	1.06	13.9	31.1	0.91
1973	57.0	31.1	0.73	57.5	36.5	0.92	14.7	26.9	0.74
1974	51.5	26.9	1.04	52.0	31.3	1.06	31.1	23.1	1.34
1975	83.4	23.1	1.35	83.5	27.6	1.53	20.4	20.9	1.53
1976	47.1	20.9	1.44	47.2	26.3	1.49	21.2	19.7	1.75
1977	40.9	19.7	1.92	-	-	-	-	-	-

Table 3.4.4. Adjusted LPUEs (N/h), by age, for selected year-classes of Pacific cod in Queen Charlotte Sound.

Age (y)		Year-class				Year-class			
		1954	1955	1956	Total	1969	1970	1971	Total
2	N/h	62.1	193.3	26.5	281.9	20.0	50.1	14.6	84.7
	%	22.0	68.6	9.4	100.0	23.6	59.2	17.2	100.0
3	N/h		147.4		214.9		44.5		75.3
4	N/h		50.6		73.8		38.1		64.4
5	N/h		12.9		18.8		10.9		18.4
6	N/h		7.5		10.9		2.1		3.5
7	N/h		2.1		3.1		1.0		1.7

Age (y)		Year-class				Year-class			
		1961	1962	1963	Total	1972	1973	1974	Total
2	N/h	18.3	61.5	43.8	123.6	32.5	72.1	46.3	150.9
	%	14.8	49.8	35.4	100.0	21.5	47.8	30.7	100.0
3	N/h		70.0		140.5		51.0		106.8
4	N/h		37.0		74.3		18.4		38.6
5	N/h		10.4		20.9		6.1		12.7
6	N/h		2.7		5.5		3.3		6.9
7	N/h		1.0		2.0		0.7		1.5

Table 3.4.5. Computation of M and F for selected strong year-classes of Pacific cod from Queen Charlotte Sound.

Year-class	Ages 3-6		Ages 3-7		Ages 4-7		Ages 4-7	
	ΣE^a	Z	ΣE	Z	ΣE	Z	$\hat{F}$	$\hat{M}$
1955	13.1	1.03	16.4	1.04	13.9	1.01	0.18	0.80
1962	24.9	1.09	32.3	1.11	28.5	1.22	0.38	0.84
1970	34.8	1.04	42.9	1.05	35.3	1.26	0.47	0.79
1973	31.1	0.93	36.5	1.03	26.9	1.04	0.36	0.68
M	1.04		1.02		0.78			
q	-8.53×10^{-7}		1.03×10^{-6}		1.32×10^{-5}			
r	-0.121		0.290		0.869			
Z	1.02		1.05		1.13			
F	-0.02		0.03		0.35			

[a] Cumulative effort in thousands of hours.

N.B.: Footnote added during proof stage of publication. Recalculation of age frequencies, based on length-frequencies grouped by month rather than by quarter year, yielded the following parameters:

	3-6	3-7	4-7
M	0.85	0.90	0.61
q	-1.11×10^{-5}	7.41×10^{-6}	2.31×10^{-5}
r	0.857	0.918	0.928
Z	1.14	1.14	1.22
F	0.29	0.24	0.61

We have concluded that age-classes 3-7 best represent the history of the fishery.

Table 3.4.6. VPA-based estimates of numbers-at-age (thousands) in the Pacific cod stock of Queen Charlotte Sound (Areas 5A + 5B), for age classes 2-7, April-March 1956-84. (Parameters based on strong year-classes and constant terminal F: M=0.78; F at age 7=0.35.)

Year[a]	Age					
	2	3	4	5	6	7
1956	3425	-	-	-	-	-
1957	4720	1214	-	-	-	-
1958	2048	1714	359	-	-	-
1959	1745	895	659	103	-	-
1960	2700	757	294	253	35	-
1961	2965	1223	309	98	95	8
1962	4902	1354	544	130	34	37
1963	3899	2218	608	240	55	6
1964	5177	1705	962	235	104	23
1965	2641	2224	672	406	86	38
1966	5002	1106	855	195	157	28
1967	1895	2095	395	334	53	58
1968	5305	800	848	112	126	11
1969	1479	2340	320	331	23	51
1970	4758	641	1023	107	140	5
1971	5846	2136	268	463	46	63
1972	4203	2535	951	110	204	9
1973	3523	1582	1013	384	44	72
1974	3487	1540	593	288	141	15
1975	4240	1390	542	199	78	42
1976	3487	1568	416	166	63	32
1977	3090	1311	458	133	51	16
1978	1755	1128	492	179	49	19
1979	-	675	249	126	64	15
1980	-	-	199	43	31	12
1981	-	-	-	31	15	11
1982	-	-	-	-	7	2
1983	-	-	-	-	-	2

[a] 1956=1956-57, etc.

Table 3.4.7. VPA-based estimates of numbers-at-age (thousands) in the Pacific cod stock of Queen Charlotte Sound (Areas 5A + 5B), for age classes 2-7, April-March 1956-84. (Parameters based on strong year-classes and variable terminal F (=qE): M=0.78; F at age 7=0.17-0.51.)

	Age					
Year[a]	2	3	4	5	6	7
1956	3767	-	-	-	-	-
1957	6354	1375	-	-	-	-
1958	2047	2457	433	-	-	-
1959	2606	895	996	137	-	-
1960	3934	1150	291	407	50	-
1961	3015	1796	490	97	166	14
1962	4445	1377	806	212	34	70
1963	3894	1995	618	359	92	6
1964	4895	1703	865	239	158	40
1965	2699	2104	672	362	88	63
1966	4025	1130	799	195	137	29
1967	1751	1644	403	310	53	48
1968	4879	733	645	114	116	11
1969	1274	2151	288	238	24	46
1970	4391	547	941	93	97	5
1971	5383	1971	225	426	40	44
1972	4084	2333	878	89	186	6
1973	3504	1526	920	353	34	64
1974	3483	1532	567	245	127	11
1975	4365	1387	538	187	59	36
1976	3756	1634	415	164	58	24
1977	3163	1427	482	132	50	13
1978	1796	1155	542	191	49	19
1979	-	690	261	148	69	15
1980	-	-	205	48	41	14
1981	-	-	-	33	17	15
1982	-	-	-	-	8	3
1983	-	-	-	-	-	2

[a] 1956=1956-57, etc.

Table 3.4.8 VPA-based estimates of F-at-age for the Pacific cod stock of Queen Charlotte Sound (Areas 5A + 5B), for age-classes 2-7 April-March 1956-84. (Parameters based on strong year-classes and constant terminal F: M=0.78; F=0.35.)

Year[a]	Age					
	2	3	4	5	6	7
1956	0.26	-	-	-	-	-
1957	0.23	0.44	-	-	-	-
1958	0.05	0.18	0.47	-	-	-
1959	0.06	0.34	0.18	0.31	-	-
1960	0.01	0.12	0.32	0.20	0.75	-
1961	0.00	0.03	0.08	0.28	0.15	0.35
1962	0.01	0.02	0.04	0.09	0.89	0.35
1963	0.05	0.06	0.17	0.06	0.08	0.35
1964	0.06	0.15	0.08	0.23	0.22	0.35
1965	0.09	0.18	0.46	0.17	0.33	0.35
1966	0.09	0.25	0.16	0.53	0.22	0.35
1967	0.08	0.12	0.48	0.19	0.78	0.35
1968	0.04	0.14	0.16	0.82	0.13	0.35
1969	0.06	0.05	0.31	0.08	0.83	0.35
1970	0.02	0.09	0.01	0.07	0.01	0.35
1971	0.06	0.03	0.12	0.04	0.86	0.35
1972	0.20	0.14	0.13	0.14	0.26	0.35
1973	0.05	0.20	0.48	0.22	0.26	0.35
1974	0.14	0.27	0.31	0.53	0.42	0.35
1975	0.21	0.43	0.40	0.36	0.10	0.35
1976	0.20	0.45	0.36	0.41	0.59	0.35
1977	0.23	0.20	0.16	0.22	0.21	0.35
1978	0.17	0.73	0.58	0.26	0.39	0.35
1979	-	0.44	0.98	0.63	0.88	0.35
1980	-	-	1.09	0.29	0.28	0.35
1981	-	-	-	0.73	1.01	0.35
1982	-	-	-	-	0.41	0.35
1983	-	-	-	-	-	0.35
Mean[b]	0.10	0.22	0.33	0.30	0.44	0.35
C.V.	0.80	0.82	0.85	0.73	0.71	-

[a] 1956=1956-57, etc.

[b] 1954-76 year-classes.

Table 3.4.9. VPA-based estimates of F-at-age for the Pacific cod stock of Queen Charlotte Sound (Areas 5A + 5B), for age-classes 2-7, April-March 1956-84. (Parameters based on strong year-classes and variable terminal F (=qE): M=0.78; F at age 7=0.17-0.51)

Year[a]	Age					
	2	3	4	5	6	7
1956	0.23	-	-	-	-	-
1957	0.17	0.37	-	-	-	-
1958	0.05	0.12	0.37	-	-	-
1959	0.04	0.34	0.12	0.23	-	-
1960	0.00	0.07	0.32	0.12	0.47	-
1961	0.00	0.02	0.06	0.28	0.08	0.17
1962	0.02	0.02	0.03	0.06	0.90	0.17
1963	0.05	0.06	0.17	0.04	0.05	0.36
1964	0.06	0.15	0.09	0.22	0.14	0.19
1965	0.09	0.19	0.46	0.19	0.33	0.20
1966	0.12	0.25	0.17	0.53	0.26	0.34
1967	0.09	0.16	0.48	0.20	0.79	0.43
1968	0.04	0.15	0.22	0.79	0.14	0.35
1969	0.06	0.05	0.35	0.12	0.79	0.39
1970	0.02	0.11	0.01	0.07	0.02	0.31
1971	0.06	0.03	0.15	0.05	1.09	0.55
1972	0.20	0.15	0.13	0.17	0.28	0.55
1973	0.05	0.21	0.54	0.24	0.33	0.40
1974	0.14	0.27	0.33	0.65	0.48	0.51
1975	0.20	0.43	0.41	0.40	0.13	0.42
1976	0.19	0.44	0.36	0.41	0.67	0.51
1977	0.23	0.19	0.15	0.22	0.21	0.43
1978	0.18	0.71	0.52	0.24	0.39	0.36
1979	-	0.43	0.92	0.50	0.80	0.35
1980	-	-	1.06	0.26	0.20	0.29
1981	-	-	-	0.67	0.82	0.23
1982	-	-	-	-	0.36	0.24
1983	-	-	-	-	-	0.29
Mean[b]	0.10	0.21	0.32	0.29	0.42	0.35
C.V.	0.76	0.81	0.82	0.73	0.73	0.34

[a] 1956=1956-57, etc.

[b] 1954-76 year-classes.

Table 3.4.10. VPA-based estimates of annual exploitation rates for the Pacific cod stock of Queen Charlotte Sound (Areas 5A + 5B), for age-classes 3-7, April-March 1961-79. (Constant terminal F: numbers in stock from Table 3.4.6.)

Year[a]	No. in stock	No. landed	Exploitation rate
1961	1732	66	0.04
1962	2100	63	0.03
1963	3127	158	0.05
1964	3029	266	0.09
1965	3427	497	0.15
1966	2342	345	0.15
1967	2935	351	0.12
1968	1897	218	0.11
1969	3065	168	0.05
1970	1916	56	0.03
1971	2977	107	0.04
1972	3808	346	0.09
1973	3095	560	0.18
1974	2578	491	0.19
1975	2250	527	0.23
1976	2246	568	0.25
1977	1968	245	0.12
1978	1867	625	0.33

[a] 1961=1961-62, etc.

Table 3.4.11. VPA-based estimates of annual exploitation rates for the Pacific cod stock of Queen Charlotte Sound (Areas 5A + 5B), for age-classes 3-7, April-March 1961-79. (Variable terminal F: numbers in stock from Table 3.4.7.)

Year[a]	No. in stock	No. landed	Exploitation rate
1961	2564	66	0.03
1962	2499	63	0.03
1963	3071	158	0.05
1964	3006	266	0.09
1965	3289	497	0.15
1966	2290	345	0.15
1967	2458	351	0.14
1968	1619	218	0.13
1969	2747	168	0.06
1970	1683	56	0.03
1971	2704	107	0.04
1972	3493	346	0.10
1973	2898	560	0.19
1974	2483	491	0.20
1975	2208	527	0.24
1976	2295	568	0.25
1977	2105	245	0.12
1978	1955	625	0.32

[a] 1961=1961-62, etc.

3.5. HECATE STRAIT

3.5.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery in Hecate Strait. Its two important co-habitants are rock sole and English sole. Annual landings of the three species oscillate non-synchronously (Fig. 3.5.1). At times a reciprocal relationship is evident, e.g., 1956-59 and 1963-68 (large landings of cod/small landings of English sole). Although subsequent stock assessments in this report are addressed to single species, the multi-species aspect of this shelf fishery is recognized and future analyses will incorporate this aspect.

Hecate Strait comprises two major areas--5C and 5D (Fig. 1). Area 5C produces 33% of the Pacific cod landed from Hecate Strait (Foucher and Westrheim 1984). Principal cod-producing grounds are Horseshoe (66%), Ole Spot (18%), and Reef Island-Cumshewa (14%) (Fig. 3.5.2). Cod occupy Horseshoe and Ole Spot grounds primarily during April-September; and Reef Island-Cumshewa during January-June. Area 5D produces 67% of the cod landed from Hecate Strait. Principal grounds are Two Peaks-Butterworth (54%) and White Rocks-Bonilla (31%). Cod occupy Two Peaks-Butterworth Ground principally during April-September; and White Rocks-Bonilla during October-March.

3.5.2. Landing statistics

Landing statistics for Hecate Strait during April-March 1956-84 are shown in Fig. 3.5.3 and Table 3.5.1. Effort exhibits a general upward trend--2,000-4,000 h during 1956-65 and 6,000-13,000 h during 1975-84. Landings continue to oscillate without trend. Zeniths occurred in 1958-59 (5,701 t), 1966-67 (8,996 t), 1975-76 (5,410 t), and 1979-80 (5,500 t). Nadirs occurred in 1961-62 (1,521 t), 1970-71 (1,182 t), and 1978-79 (2,298 t). Landings and effort are not synchronous. Rather, effort generally peaks after the peaks in landings. LPUEs oscillate similarly to, but not synchronously with, landings and exhibit a downward trend. Zeniths occurred in 1957-58 (1,887 kg/h), 1964-65 (1,646 kg/h), 1973-74 (1,143 kg/h), and 1979-80 (476 kg/h). Zeniths generally occur one year before the corresponding zeniths in landings.

Summary. Abundance of cod, based on landing statistics, is currently at a relatively low level, but similar phenomena have been observed in 1960-63 and 1969-72.

3.5.3. Age composition

Annual age composition, in numbers landed per hour trawled (N/h), of Pacific cod landings from Hecate Strait during April-March 1960-84 are contained in Table 3.5.2, together with corresponding landings (t) and effort (h). Source of this compilation is Foucher and Westrheim (1984). Principal components throughout the time series are age-classes 2-4. Recruitment is thought to be complete at age 3. Strong year-classes, based on LPUE at age 2, are 1962, 1965, 1970-72, and 1977.

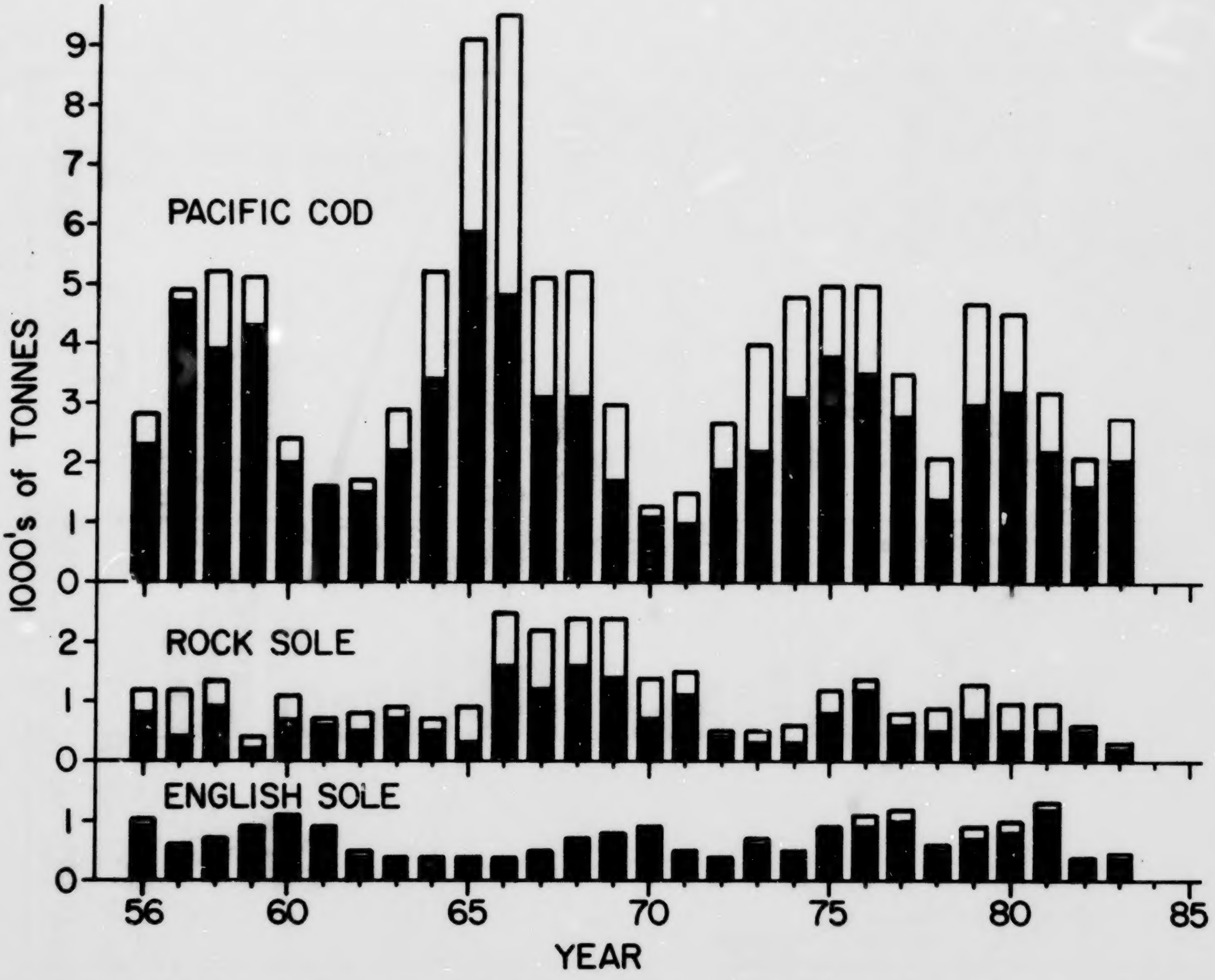


Fig. 3.5.1. Canada-U.S. landings (t) of Pacific cod, rock sole, and English sole from Hecate Strait (Areas 5C and 5D), January-December 1956-84. (Shaded areas = landings from Area 5D.)

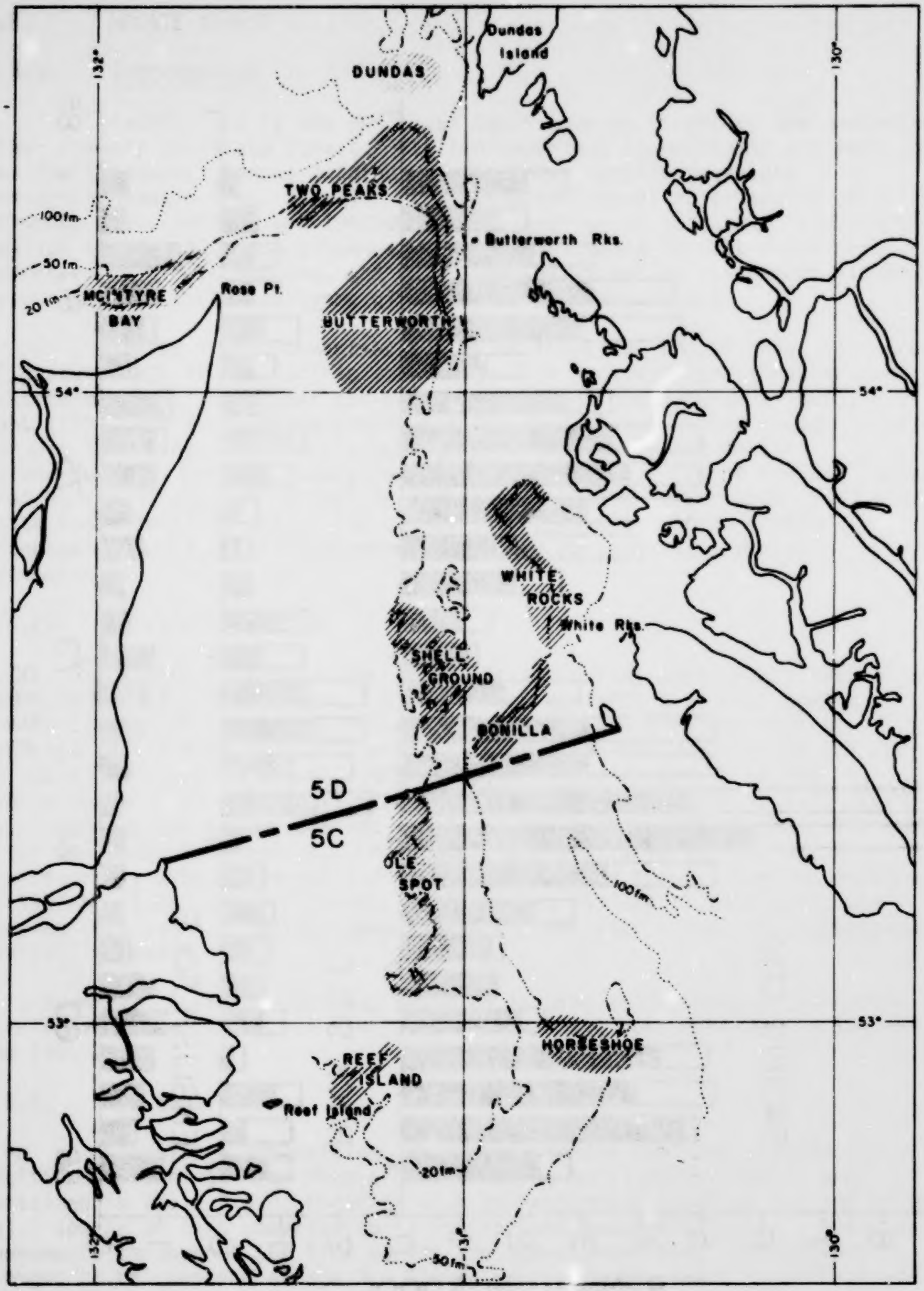

Dundas Island
DUNDAS
132°
130°
TWO PEAKS
100fm
Butterworth Rks.
50fm
20fm
MCINTYRE BAY
Rose Pt.
BUTTERWORTH
54°
WHITE ROCKS
White Rks.
SHELL GROUND
BONILLA
5D
5C
OLE SPOT
100fm
53°
HORSESHOE
REEF ISLAND
Reef Island
20fm
131°
50fm

Fig. 3.5.2. Important shelf trawling grounds in Hecate Strait.

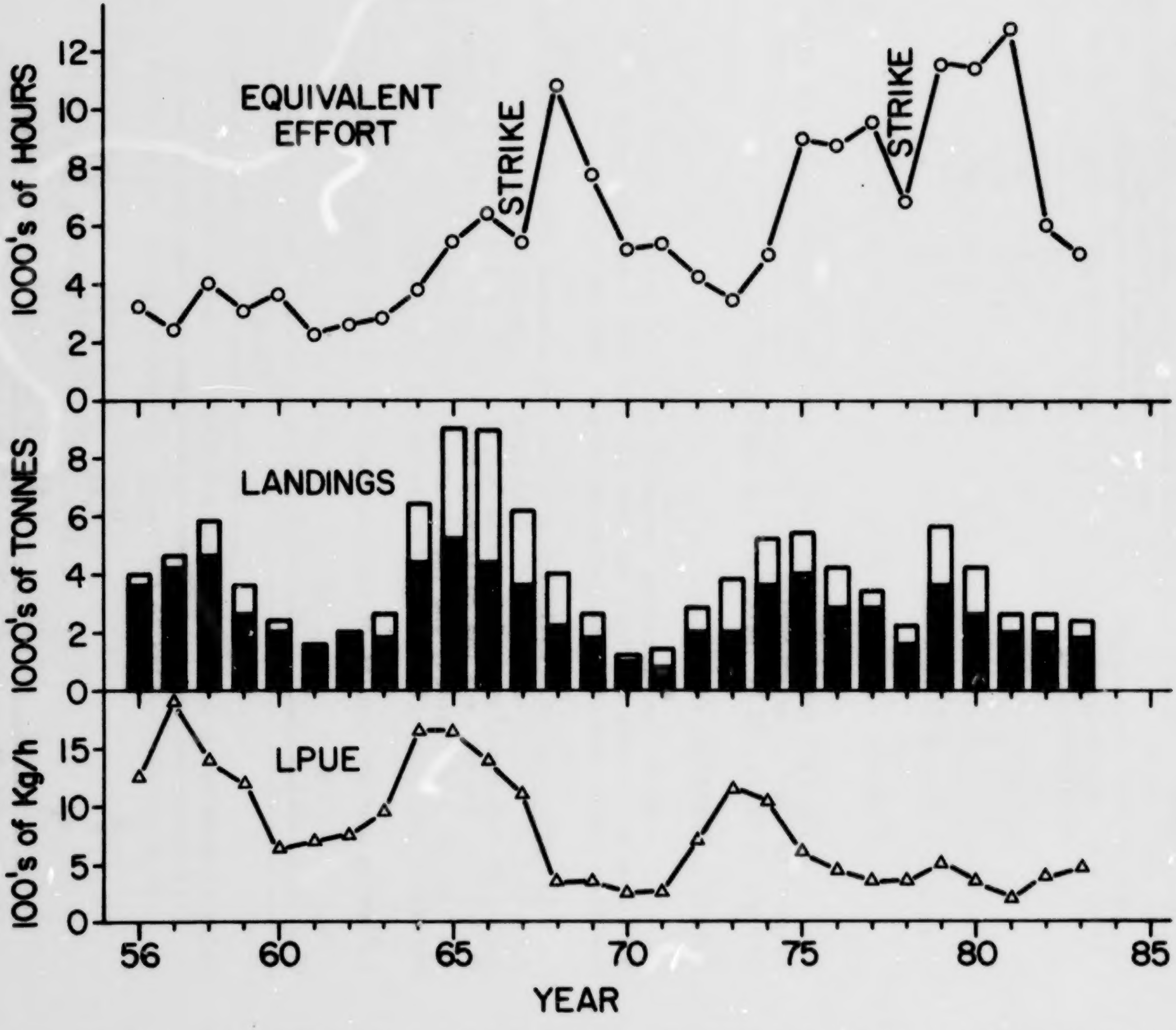


Fig. 3.5.3. Standardized Canada-U.S. landing statistics for Pacific cod from Hecate Strait (Areas 5C and 5D), April-March, 1954-84. (Shaded areas = landings from Area 5D).

The Hecate Strait age-composition matrix exhibits anomalies similar to those for Queen Charlotte Sound and west Vancouver Island. For example, the 1961-63 year classes:

Age class	Year-class LPUE (N/h)		
	1961	1962	1963
2	109.4	356.2	54.8
3	246.7	357.2	211.5
4	164.3	155.1	66.7
5	50.2	28.6	11.1
6	10.9	3.8	3.1
7	1.6	1.4	0.6

The 1962 year-class gradually loses its relative importance with respect to the two neighbouring year-classes. This phenomenon is currently thought to be caused by inaccurate age determination.

3.5.4. Mortality rates

Methods for computing mortality rates for Pacific cod from Hecate Strait were the same as those employed for cod from Queen Charlotte Sound (Section 3.4.4) and off west Vancouver Island (Section 3.3.4).

All year-classes. Estimates of Z for year-classes 1960-77 ranged from 0.42 to 1.63 for age-classes 3-6; 0.53-1.48 for age-classes 3-7; and 0.74-1.61 for age-classes 4-7 (Table 3.5.3) -- 92% of the Z values ranged from 0.74-1.63. Notable are the relatively high Z values (1.54-1.61) sustained by the 1962-63 year-classes, and the relatively close, and direct, relationship between Z and cumulative effort for the recent year-classes.

Following are the results of the computations for the other parameters:

Parameter	Age-classes		
	3-6	3-7	4-7
Z	1.10	1.14	1.25
M	0.62	0.92	1.08
F	0.48	0.21	0.17
q[a]	1.79×10^{-5}	6.52×10^{-6}	6.48×10^{-6}
r[a]	0.512	0.276	0.227

[a] For regression of Z on effort.

Only the parameters for age-classes 3-6 seem fairly "reasonable"-- r was highest (0.512). Estimates of F for ages 3-7 (0.21) and ages 4-7 (0.17) were deemed too low.

Strong year-classes. For strong year-classes 1962, 1965, and 1970-72, computations of "adjusted" LPUEs are shown in Table 3.5.4. Results of parameter computations are shown in Table 3.5.5. Parameters computed for ages 3-7 appeared to be "reasonable"--$Z = 1.27$; $M = 0.65$; $F = 0.62$; and $q = 1.67 \times 10^{-5}$. Estimates of F (= qE) and M (= Z-F) for the individual strong year-classes were as follows:

Parameter	Year class 1962	 1965	 1970-72
Z	1.39	1.13	1.28
F	0.60	0.56	0.67
M	0.79	0.57	0.61

Other estimates. A comparison of current results for Hecate Strait with those in previous studies is summarized below:

Source	Method	Parameter Z	 F	 M
Ketchen (1964)	Tagging, 1960-61	1.05-1.53	-	-
	Growth, virgin stock	-	-	<0.83-0.99
Stocker (1981)	Length frequencies	1.05	0.67	0.38
Fournier (1983)	Age-structured model	-	-	0.65
This study	Length frequencies			
	a) All year-classes	1.10	0.48	0.62
	b) Strong year-classes	1.13-1.39	0.56-0.67	0.57-0.79

All studies estimated Z to be large, and M to be large with respect to F. If these estimates are reasonable, then fishing has not necessarily been a major factor in determining the abundance of Pacific cod in Hecate Strait.

3.5.5. Virtual population analysis

Two VPAs were undertaken for Pacific cod in Hecate Strait. One utilized parameters based on age-classes 3-6 for all year-classes, and the other used parameters based on age-classes 3-7 for selected strong year-classes (see Section 3.5.4). In both cases, M and terminal F values were held constant. Appropriate parameters are listed below:

	F	M
All year-classes	0.48	0.62
Strong year-classes	0.62	0.65

Estimated numbers at age 2. The all-year-class VPA estimates of cod at age 2 ranged from 2.3 million in 1968 to 13.8 million in 1964 (Table 3.5.6). corresponding estimates based on the strong-year-class VPA ranged from 2.5 million in 1968 to 14.5 million in 1964 (Table 3.5.7). In both cases, abundance of age-2 cod was relatively high during 1970-78.

F values at age. For the all-year-classes VPA for selected fully recruited age-classes (3-7), F ranged from 0.38 (age 3) to 0.59 (age 5) (Table 3.5.8). For the strong-year-classes VPA, corresponding values were 0.37 (age 3) to 0.62 (ages 5 and 7) (Table 3.5.9). During 1979-82, F values were above average for all age-classes, as in 1966-69.

Exploitation rates. For the all-year-classes VPA, exploitation rates among years (1965-78) for age-classes 3-7 ranged from 0.08 (1971) to 0.41 (1966, 1967) (Table 3.5.10), with a mean of 0.27. Corresponding values for the strong-year-class VPA were the same (Table 3.5.11). Exploitation rate declined sharply during 1975-78 (0.39--0.17) in sharp contrast to the relatively high effort expended in three of the four years -- 9,100, 8,800, 9,700, and 6,700 h, respectively (Table 3.5.1).

A second method for estimating exploitation rates employed the formula of Ricker (1975), $\mu = AF/Z$, where $A = 1-e^{-Z}$. Results of these computations are listed below:

Parameter	All year-classes	Strong year-classes
F^a	0.48	0.62
Z^a	1.10	1.27
μ	0.29	0.35

[a] See Section 3.5.4.

The relative importance of M is evident here also.

Summary. Results of the two VPAs are quite similar for 1958-78, with respect to estimated numbers at age 2, (2.3-13.8 million vs. 2.5-14.5 million), F (0.38-0.59 vs 0.37-0.62), and exploitation rate (0.27). Ricker's (1975) method of estimating exploitation rate yielded 0.29 for all year-classes, and 0.35 for strong year-classes. The relatively low values of μ are caused by the relatively large component of M in Z ($Z = F+M$).

3.5.6. Conclusions

The current low level of abundance of Pacific cod in Hecate Strait appears to be one more nadir in the historic quasi-cyclic oscillations. These oscillations reflect the variable recruitment, which in turn appears to be largely determined by factors other than fishing--water temperature is currently considered to be an important factor. While adverse (warm) water temperatures during 1981-84 preclude any immediate improvement in recruitment, fishing effort (and presumably F) has declined substantially since 1981-82.

3.5.7. Recommendations

Two alternative yield options are recommended, based largely on potential risk -- one optimistic and the other cautious. The optimistic yield option recommends no regulation, based on the assumption that the fishery is largely self-regulating. That is, effort will not rise before cod abundance rises. The cautious yield option recommends a ceiling on landings, not to exceed the mean of previous nadirs ($\bar{x}$ = 1,700 t). This would ensure that no sudden increase in effort would occur, for whatever cause.

Table 3.5.1. Canada-U.S. landing statistics for Pacific cod from Hecate Strait (Areas 5C+5D), April-March 1956-84.

Year	Standardized equivalent effort (h)	Landings (t)			LPUE (kg/h)		
		Total	5C	5D	Total[a]	5C[b]	5D[c]
1956-57	3,102	3,924	436	3,488	1,265	1,671	1,109
1957-58	2,424	4,575	278	4,297	1,887	184	2,020
1958-59	4,072	5,701	1,200	4,501	1,400	1,748	1,110
1959-60	2,919	3,517	824	2,693	1,205	1,158	1,235
1960-61	3,627	2,390	400	1,990	659	363	790
1961-62	2,176	1,521	34	1,487	699	212	726
1962-63	2,670	2,056	164	1,892	770	384	872
1963-64	2,792	2,658	760	1,898	952	1,341	606
1964-65	3,842	6,324	1,927	4,397	1,646	1,597	1,690
1965-66	5,490	8,927	3,673	5,254	1,626	1,207	2,012
1966-67	6,317	8,996	4,667	4,329	1,424	1,473	1,362
1967-68	5,499	6,115	2,557	3,558	1,112	964	1,283
1968-69	10,788	3,927	1,631	2,296	364	359	367
1969-70	7,878	2,576	822	1,754	327	237	379
1970-71	5,230	1,182	250	932	226	57	257
1971-72	5,446	1,307	490	817	240	274	224
1972-73	4,208	2,899	821	2,078	689	819	632
1973-74	3,344	3,822	1,746	2,076	1,143	1,298	1,002
1974-75	4,931	5,247	1,669	3,578	1,064	987	1,106
1975-76	9,092	5,410	1,357	4,053	595	454	646
1976-77	8,793	4,168	1,339	2,829	474	605	400
1977-78	9,670	3,462	629	2,833	358	370	356
1978-79	6,719	2,298	740	1,558	342	520	236
1979-80	11,555	5,500	1,830	3,670	476	620	386
1980-81	11,455	4,227	1,667	2,560	369	482	303
1981-82	12,951	2,642	626	2,016	204	253	190
1982-83	5,955	2,507	554	1,953	421	207	482
1983-84	5,093	2,292	553	1,739	450	454	449

[a] Mean. Weighted by April-September landings from appropriate major area.

[b] Horseshoe, April-September.

[c] Two Peaks-Butterworth, April-September.

Table 3.5.2. Canada-U.S. landings(t) of Pacific cod, standardized equivalent effort(h) and number/h by age, from Hecate Strait (Areas 5C + 5D) during April-March 1960-83.

Year[a]	C-U.S. Land (t)	C-U.S. Eff (h)	Age									
			1	2	3	4	5	6	7	8	9	10
1960	2390	3627	-	46.1	140.7	58.8	13.3	5.8	2.4	0.6	0.2	-
1961	1521	2176	-	40.1	124.0	67.7	19.0	7.7	2.5	1.4	0.4	-
1962	2056	2670	1.3	63.6	126.8	67.4	27.7	7.1	5.2	1.0	1.0	-
1963	2658	2792	8.9	109.4	180.3	81.8	34.5	7.4	1.3	1.0	0.2	0.1
1964	6324	3842	1.5	356.2	246.7	110.7	30.9	8.5	1.0	0.6	0.1	-
1965	8927	5490	0.5	54.8	357.2	164.3	31.0	11.9	0.4	0.5	-	-
1966	8996	6317	1.0	72.1	211.5	155.1	50.2	12.0	3.2	0.6	0.2	0.1
1967	6115	5499	-	146.5	211.7	66.7	28.6	10.9	2.9	0.9	0.4	0.1
1968	3927	10788	0.4	21.5	65.9	25.5	11.1	3.8	1.6	0.3	0.1	-
1969	2576	7878	0.1	24.4	41.3	34.8	9.2	3.1	1.4	0.3	0.1	0.1
1970	1182	5230	-	50.8	31.9	14.8	5.6	1.3	0.6	0.2	0.0	0.2
1971	1307	5446	0.8	48.3	26.1	18.3	7.8	1.2	0.7	0.7	-	-
1972	2899	4208	0.5	208.2	84.8	42.1	12.3	3.4	2.2	0.1	0.9	-
1973	3822	3344	7.8	204.9	227.7	78.4	16.7	9.0	1.2	0.6	0.8	0.2
1974	5247	4931	0.5	233.7	119.4	82.7	30.4	8.2	1.7	0.8	0.8	0.1
1975	5410	9092	0.1	62.7	117.7	44.4	20.4	3.9	4.2	1.5	0.6	-
1976	4168	8793	0.2	65.3	97.6	27.5	9.8	2.7	1.6	0.2	0.2	-
1977	3462	9670	0.1	89.0	61.2	27.1	4.9	3.3	1.1	-	-	-
1978	2298	6719	3.1	19.0	53.1	40.5	10.6	1.5	1.3	0.3	-	-
1979	5500	11555	0.6	117.8	54.6	45.6	11.7	4.3	0.8	0.4	0.1	0.1
1980	4227	11455	0.5	54.3	66.4	35.7	12.2	2.3	1.2	-	-	-
1981	2642	12951	1.1	34.0	31.6	20.8	6.8	1.4	0.6	-	-	-
1982	2507	5955	0.6	34.7	66.1	42.1	11.8	3.0	0.7	0.1	0.1	-
1983	2292	5093	0.4	39.9	66.0	47.9	15.3	4.8	0.8	0.5	0.1	0.1

[a] 1960=1960-61, etc.

Table 3.5.3. Cumulative LPUE (ΣLPUE), cumulative effort (ΣE), and estimated Z, by year-class, over selected age-classes of Pacific cod landed from Hecate Strait (Areas 5C+5D).

Year-class	Ages 3-6			Ages 3-7			Ages 4-7		
	ΣLPUE (N/h)	ΣE (10^3 h)	Z	ΣLPUE (N/h)	ΣE (10^3 h)	Z	ΣLPUE (N/h)	ΣE (10^3 h)	Z
1960	334.0	18.4	.94	336.9	23.9	1.05	156.6	21.1	1.19
1961	472.1	21.1	1.05	473.7	31.9	1.28	227.0	28.1	1.54
1962	544.7	28.1	1.53	546.1	36.0	1.48	188.9	30.5	1.61
1963	292.4	30.5	1.45	293.0	35.7	1.48	81.5	29.4	1.54
1964	247.7	29.4	1.63	248.4	34.8	1.44	36.7	29.3	1.27
1965	107.5	29.3	1.38	109.7	33.6	1.02	43.8	22.8	.98
1966	67.3	22.8	.81	68.5	26.1	.86	27.2	18.2	.84
1967	71.5	18.2	.42	73.2	23.2	.66	41.3	17.9	.74
1968	93.1	17.9	.44	97.3	27.0	.53	71.2	21.6	.76
1969	197.5	21.6	1.02	199.1	30.4	1.09	114.3	26.2	1.37
1970	333.5	26.2	1.47	334.6	35.8	1.41	106.9	32.5	1.50
1971	176.9	32.5	1.23	178.2	39.2	1.16	58.8	34.3	1.17
1972	151.6	34.3	1.48	152.4	45.8	1.29	34.7	36.7	1.19
1973	139.6	36.7	1.03	140.8	48.2	1.06	43.2	39.4	1.03
1974	115.7	39.4	1.11	116.3	52.4	1.21	55.1	42.7	1.43
1975	112.3	42.7	1.22	113.0	48.6	1.21	59.9	41.9	1.47
1976	100.1	41.9	1.04	100.9	47.0	1.09	46.3	35.5	1.22
1977	103.8	35.5	.86	-	-	-	-	-	-

Table 3.5.4. Adjusted LPUEs (N/h), by age, for selected year-classes of Pacific cod in Hecate Strait.

Age (y)		Year-class				Year-class			
		1961	1962	1963	Total	1964	1965	1966	Total
2	N/h	109.4	356.2	54.8	520.4	72.1	146.5	21.5	240.1
	%	21.0	68.5	10.5	100.0	30.0	61.0	9.0	100.0
3	N/h		558.5		815.4		194.5		318.9
4	N/h		264.5		386.1		45.8		75.1
5	N/h		61.6		89.9		13.8		22.6
6	N/h		12.2		17.8		3.6		5.9
7	N/h		2.5		3.6		2.5		4.1

Age (y)		Year-class			
		1969	1970-1972	1973	Total
2	N/h	48.3	590.4	62.7	701.4
	%	6.9	84.2	8.9	100.0
3	N/h		544.9		647.2
4	N/h		219.0		260.1
5	N/h		64.1		76.1
6	N/h		11.9		14.1
7	N/h		3.9		4.6

Table 3.5.5. Computations of M and F for selected strong year-classes of Pacific cod from Hecate Strait.

Year-class	Ages 3-6		Ages 3-7		Ages 4-7	
	ΣE	Z	ΣE	Z	ΣE	Z
1962	28.1	1.29	36.0	1.39	30.5	1.56
1965	29.3	1.32	33.6	1.13	22.8	1.01
1970-72	31.0	1.27	40.3	1.28	34.6	1.38
M	1.54		.65		.25	
q	8.40×10^{-6}		1.67×10^{-5}		3.65×10^{5}	
r	-0.486		+ 0.435		+ 0.780	
Z	1.29		1.27		1.32	
F	-0.25		0.62		1.07	

Table 3.5.6. VPA-based estimates of numbers-at-age (thousands) in the Pacific cod stock of Hecate Strait (Areas 5C + 5D), for age-classes 2-7, April-March 1960-84. (Parameters based on all year-classes: M=0.62; F at age 7=0.48)

Year[a]	Age					
	2	3	4	5	6	7
1960	3150	-	-	-	-	-
1961	5582	1574	-	-	-	-
1962	7181	2940	653	-	-	-
1963	11683	3749	1338	224	-	-
1964	13768	6048	1657	555	54	-
1965	6903	6410	2582	593	214	7
1966	5619	3481	2068	762	198	69
1967	5091	2694	940	441	191	54
1968	2332	2157	639	250	126	61
1969	2677	1086	661	153	52	39
1970	5614	1305	357	166	33	11
1971	5323	2824	582	138	69	13
1972	7627	2678	1413	241	44	32
1973	6064	3473	1183	631	93	14
1974	6450	2771	1324	453	300	29
1975	6486	2659	1071	424	138	132
1976	5581	3080	685	295	99	49
1977	6125	2583	1051	198	98	36
1978	4877	2674	970	379	72	31
1979	-	2525	1181	331	153	32
1980	-	-	910	270	84	48
1981	-	-	-	206	50	27
1982	-	-	-	-	50	14
1983	-	-	-	-	-	15

[a] 1960=1960-61, etc.

Table 3.5.7. VPA-based estimates of numbers-at-age (thousands) in the Pacific cod stock of Hecate Strait (Areas 5C + 5D) for age-classes 2-7, April-March 1960-84. (Parameters based on strong year-classes: M=0.65; F at age 7=0.62.)

	Age					
Year[a]	2	3	4	5	6	7
1960	3371	-	-	-	-	-
1961	5882	1648	-	-	-	-
1962	7689	3007	672	-	-	-
1963	12493	3897	1330	226	-	-
1964	14470	6277	1677	534	52	-
1965	7268	6585	2610	576	196	6
1966	5855	3587	2085	748	184	57
1967	5279	2747	958	428	175	45
1968	2464	2194	646	249	116	50
1969	2846	1122	654	151	49	32
1970	5727	1347	358	154	30	9
1971	5658	2799	583	134	60	11
1972	7981	2764	1357	235	41	27
1973	6434	3553	1189	584	86	12
1974	6721	2867	1331	438	264	24
1975	6813	2698	1084	412	125	110
1976	5893	3162	677	290	89	41
1977	6510	2665	1053	186	91	30
1978	5213	2791	980	368	64	26
1979	-	2619	1201	324	142	26
1980	-	-	925	268	77	40
1981	-	-	-	204	46	22
1982	-	-	-	-	47	12
1983	-	-	-	-	-	12

[a] 1960=1960-61, etc.

Table 3.5.8. VPA-based estimates of F-at-age for the Pacific cod stock of Hecate Strait (Areas 5C + 5D), for age-classes 2-7, April-March 1960-84. (Parameters based on all year-classes: M=0.62; F at age 7=0.48.)

Year[a]	Age					
	2	3	4	5	6	7
1960	0.07	-	-	-	-	-
1961	0.02	0.26	-	-	-	-
1962	0.03	0.17	0.45	-	-	-
1963	0.04	0.20	0.26	0.81	-	-
1964	0.14	0.23	0.41	0.33	1.46	-
1965	0.06	0.51	0.60	0.47	0.51	0.48
1966	0.12	0.69	0.93	0.76	0.68	0.48
1967	0.24	0.82	0.71	0.63	0.53	0.48
1968	0.14	0.56	0.81	0.95	0.56	0.48
1969	0.10	0.49	0.76	0.91	0.92	0.48
1970	0.07	0.19	0.33	0.26	0.33	0.48
1971	0.07	0.07	0.26	0.52	0.14	0.48
1972	0.17	0.20	0.19	0.33	0.53	0.48
1973	0.16	0.34	0.34	0.12	0.55	0.48
1974	0.27	0.33	0.52	0.57	0.20	0.48
1975	0.12	0.74	0.67	0.83	0.41	0.48
1976	0.15	0.46	0.62	0.48	0.38	0.48
1977	0.21	0.36	0.40	0.38	0.54	0.48
1978	0.04	0.20	0.46	0.29	0.20	0.48
1979	-	0.40	0.86	0.75	0.54	0.48
1980	-	-	0.87	1.06	0.52	0.48
1981	-	-	-	0.79	0.64	0.48
1982	-	-	-	-	0.61	0.48
1983	-	-	-	-	-	0.48
Mean[b]	0.12	0.38	0.55	0.59	0.54	0.48
C.V.	0.61	0.56	0.42	0.45	0.54	-

[a] 1960=1960-61, etc.

[b] 1958-76 year-classes.

Table 3.5.9. VPA-based estimates of F-at-age for the Pacific cod stock of Hecate Strait (Areas 5C + 5D), for age-classes 2-7, April-March 1960-84. (Parameters based on strong year-classes: M=0.65; F at age 7=0.62.)

	Age					
Year[a]	2	3	4	5	6	7
1960	0.07	-	-	-	-	-
1961	0.02	0.25	-	-	-	-
1962	0.03	0.17	0.44	-	-	-
1963	0.04	0.19	0.26	0.82	-	-
1964	0.14	0.23	0.42	0.35	1.58	-
1965	0.06	0.50	0.60	0.49	0.58	0.62
1966	0.11	0.67	0.93	0.80	0.76	0.62
1967	0.23	0.80	0.70	0.65	0.60	0.62
1968	0.14	0.56	0.81	0.97	0.64	0.62
1969	0.10	0.49	0.80	0.97	1.03	0.62
1970	0.07	0.19	0.33	0.29	0.38	0.62
1971	0.07	0.07	0.26	0.54	0.16	0.62
1972	0.16	0.19	0.19	0.35	0.61	0.62
1973	0.16	0.33	0.35	0.14	0.62	0.62
1974	0.26	0.32	0.52	0.60	0.23	0.62
1975	0.12	0.73	0.67	0.88	0.47	0.62
1976	0.14	0.45	0.64	0.51	0.43	0.62
1977	0.20	0.35	0.40	0.42	0.62	0.62
1978	0.04	0.19	0.46	0.31	0.23	0.62
1979	-	0.39	0.85	0.79	0.62	0.62
1980	-	-	0.86	1.10	0.59	0.62
1981	-	-	-	0.83	0.72	0.62
1982	-	-	-	-	0.69	0.62
1983	-	-	-	-	-	0.62
Mean[b]	0.11	0.37	0.55	0.62	0.61	0.62
C.V.	0.62	0.56	0.42	0.44	0.51	-

[a] 1960=1960-61, etc.

[b] 1958-76 year-classes.

Table 3.5.10. VPA-based estimates of annual exploitation rates for the Pacific cod stock of Hecate Strait (Areas 5C + 5D), for age classes 3-7, April-March 1965-79. (All year-classes: numbers in stock from Table 3.5.6.)

Year[a]	No. in stock	No. landed	Exploitation rate
1965	9806	3101	0.32
1966	6579	2729	0.41
1967	4320	1765	0.41
1968	3233	1164	0.36
1969	1990	708	0.36
1970	1872	283	0.15
1971	3625	295	0.08
1972	4409	609	0.14
1973	5394	1114	0.21
1974	4877	1195	0.25
1975	4424	1733	0.39
1976	4208	1225	0.29
1977	3967	944	0.24
1978	4126	719	0.17

[a] 1965=1965-66, etc.

Table 3.5.11. VPA-based estimates of annual exploitation rates for the Pacific cod stock of Hecate Strait (Areas 5C + 5D), for age-classes 3-7, April-March 1965-79. (Strong year-classes: numbers in stock from Table 3.5.7.)

Year[a]	No. in stock	No. landed	Exploitation rate
1965	9974	3101	0.31
1966	6662	2729	0.41
1967	4354	1765	0.41
1968	3256	1164	0.36
1969	2008	708	0.35
1970	1898	283	0.15
1971	3587	295	0.08
1972	4424	609	0.14
1973	5425	1114	0.21
1974	4923	1195	0.24
1975	4429	1733	0.39
1976	4259	1225	0.29
1977	4025	944	0.23
1978	4229	719	0.17

[a] 1965=1965-66, etc.

3.6. WEST COAST QUEEN CHARLOTTE ISLANDS (Area 5E)

No analysis. Cod abundance negligible.

4. FLATFISH

by J. Fargo

4.1. Coastwide

Yield options are not proposed for flatfish species on a coastwide basis.

4.2. Strait of Georgia

Yield options are not proposed for flatfish species for this region.

4.3. West coast of Vancouver Island

Dover sole and Petrale sole are significant flatfish species off the west coast of Vancouver Island. The fishery for Dover sole is a deepwater fishery in winter while the Petrale sole fishery is in deepwater in Area 3D in winter and in shallow water in summer in Area 3C.

4.3.1 Dover sole

4.3.1.1. Introduction

Historically, the fishery for Dover sole (*Microstomus pacificus*) in Areas 3C and 3D has been limited mostly to shallow water for the Canadian fleet (mainly in Area 3C) but not so for the U.S. fleet. Landings by the U.S. fleet in 3CN and 3D greatly exceeded those of the Canadian fleet over the time period 1954-77.

In 1978 after IDP exploration surveys to examine deepwater fish populations off the west coast of the Queen Charlottes, interest in deepwater stocks off the west coast of Vancouver Island was re-awakened. The fishery at present involves a few Canadian vessels with landings confined mostly to the spring quarter of the year in Area 3C. These boats are specialized to carry on a deepwater fishery (200-400 fath). Most of Area 3D is still unexploited. Principal fishing areas include Estevan Deep and S. Clayoquot Canyon. In 1983 the fishery was less significant than in 3 previous years.

Landing statistics and results of a biomass survey are used in the following stock assessment.

4.3.1.2. Landing statistics

Landing statistics for Dover sole in Areas 3C+3D are given in Table 4.3.1. Landings until the late 1970s were predominantly from the U.S. fleet and effort figures for these landings are unavailable. Two surges in Canadian landings are recorded, one in the early 1970s and a second in the early 1980s.

The increase in Canadian landings in the early 1970s was largely due to results of the G.B. REED exploratory surveys in 1967-69. Effort was subsequently abandoned due to inadequate gear for deepwater fisheries.

The increase in Canadian landings in the early 1980s was partly due to the access provided to Canadian trawlers to the logs of U.S. and Canadian exploratory surveys in the 1950s and 1960s.

4.3.1.3. Biomass estimate

In 1981, the M/V ARCTIC HARVESTER conducted a swept-area trawl survey to estimate Dover sole biomass in Areas 3C and 3D (Carter et al. 1981). An estimate of 5000 t ± (80%) (commercial size fish) was obtained over trawlable bottom in Estevan Deep and S. Clayoquot Canyon. The biomass estimate used is considered to be a minimum estimate as only a relatively small portion of the habitat area for Dover sole was surveyed in 1981.

4.3.1.4. Conclusions

Results of the 1981 biomass survey cannot be used to recommend a TAC for the species in International Areas 3C and 3D. Collection of detailed landing statistics and establishing a biological data base is necessary before accurate estimates of MSY can be obtained.

4.3.1.5. Yield options

No regulations are recommended for Dover sole in Area 3C, 3D.

4.3.2. Petrale sole

4.3.2.1. Introduction

The petrale sole (Eopsetta jordani) population off the west coast of Vancouver Island is considered to be comprised of two stocks on the basis of tagging experiments conducted in the 1960's (Ketchen and Forrester 1966). The bulk of the landings from the "northern" stock have come from shallow water summer fisheries in 3D, 5A, B, C, and D, and a deepwater winter fishery in Area 3D. The "southern" stock is exposed to a shallow water summer fishery in the Canadian portion of Area 3C and numerous deepwater winter fisheries in U.S. waters from Cape Flattery Spit (Area 3C-S) to Willipa Deep (Area 3A).

Landing statistics and a multivariate analysis are used in the following stock assessment.

4.3.2.2. Landing statistics

Petrale sole landings from the "southern" stock show peaks in the late 1940s, early 1960s and mid-1970s (Table 4.3.2.). All of these may have been the result of warm water years which favour recruitment (Ketchen and Forrester 1966).

Landings for the "northern stock" exhibit peaks in the late 1940s, mid-1950s and mid-1960s (Table 4.3.3.). Peak catches in the 1940s and 1950s were supported by series of consecutive strong year-classes. The discovery of the "northern" stock spawning ground in the late 1950s by the U.S. fleet contributed to the increase in landings over the latter period. Effort figures are unavailable for U.S. landings over most of the time series.

4.3.2.3. Assessment

Details and conclusions of two separate studies on petrale sole production vs environment have been reported earlier, Stocker (1981). More recently, a multvariate analysis was performed on the indices of petrale sole

Table 4.3.1. Canada-U.S. Dover sole landings (t) Area 3C and 3D.

Year	Canadian[a]	U.S.[b]	Total
1954	28	388	416
1955	92	461	553
1956	54	611	665
1957	48	274	322
1958	36	304	340
1959	6	372	378
1960	5	569	574
1961	30	559	589
1962	8	901	909
1963	28	328	356
1964	11	230	241
1965	14	202	216
1966	1	115	116
1967	8	90	98
1968	3	40	43
1969	29	82	111
1970	192	388	580
1971	207	78	285
1972	11	45	56
1973	8	59	67
1974	13	107	120
1975	15	102	117
1976	23	176	199
1977	47	192	239
1978	94	61	155
1979	54	15	69
1980	277	10	287
1981	255	6	261
1982	200	*	-
1983	94	*	-

*U.S. landings not available.

[a] Canadian landings excluding dumped fish and discards.

[b] 1954-62 from Ketchen (1976) (including U.S. portion of 3C).
1963-76 from Ketchen (1976) using WDF progress reports to eliminate landings from U.S. portion of 3C.

year-class strength, stock size, and sea surface temperature using data from Ketchen and Forrester (1966). Response surface analysis (Schnute and McKinnell, 1984) was the technique employed.

Temperature explained 42% of the variation in Petrale sole year-class strengths from 1939-58. These results were similar to those reported by Ketchen and Forrester (1966). Year-class strength increased with increasing temperature to a maximum temperature of 9.4°C. The response surface analysis indicated a linear relationship between the two variables.

Stock size was added to the analysis as a second independent variable and no improvement in fit resulted.

Using the B statistic described in Schnute and McKinnel (1984), temperature was significant at the 0.1 P level while stock size was not significant.

The effects of the fishery on year-class strength and stock size were not evaluated due to the lack of effort/LPUE data over the time period.

4.3.2.4. Conclusions

Available evidence suggests that year-class strength is not correlated with the size of petrale sole spawning stock. Temperature is positively correlated with petrale sole year-class strength. The surface temperatures in 1981, 1983 were high enough to produce stronger year-classes, but the effects of the higher temperatures in recent years will not be expressed until the late 1980s.

It is also possible that a critical stock size exists for petrale sole, i.e. at stock sizes below the critical level, production of strong year-classes does not occur, as demonstrated for rock sole in Hecate Strait (See Section 4.5).

4.3.2.5. Yield options

In 1967, after results of a study of petrale sole population dynamics were published (Ketchen and Forrester 1966), the Technical Sub-Committee of the Canada-U.S. Groundfish Committee recommended abolishing regulations for petrale sole stocks on the Pacific coast (in place since 1958).

A 40,000 lb. trip limit is currently in effect for petrale sole in Areas 3C and 3D from January-March. This regulation is the result of a request by industry.

1) Conservative option - it is possible that a "critical" (minimum) stock size may exist for petrale sole. The previous analyses regarding year-class strength vs stock size were conducted using data when petrale sole stocks were at a higher level of abundance than at present. The trip limit should be retained to support the concept of a "critical" stock size.

Table 4.3.2. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C)--the area occupied by the "southern stock," 1942-83.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	?		1,561	1963	90	658	748
1943	?	-	2,264	1964	71	530	601
1944	?	-	1,489	1965	140	658	798
1945	?	-	718	1966	118	512	630
1946	?	-	906	1967	106	259	365
1947	?	-	627	1968	114	233	347
1948	?	-	1,321	1969	255	142	397
1949	?	-	1,178	1970	80	198	278
1950	?	-	854	1971	74	523	597
1951	?	-	794	1972	22	561	583
1952	?	-	948	1973	211	452	663
1953	?	-	748	1974	230	684	914
1954	?	-	664	1975	474	465	939
1955	?	-	415	1976	304	453	757
1956	40	585	625	1977	157	311	468
1957	9	629	638	1978	287	126	413
1958	19	609	628	1979	256	92	348
1959	33	1072	1105	1980	147	115	262
1960	233	974	1207	1981	125	180	305
1961	375	1109	1484	1982	45	232	277
1962	215	850	1065	1983	179	183	183

Table 4.3.3. Canada-U.S. landings (t) of petrale sole from "northern stock," 1942-83.

Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total	Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total
1942	-	-	-	-	1963	202	537	82	821
1943	-	-	-	-	1964	183	421	163	767
1944	499	303	-	802	1965	300	418	202	920
1945	270	1,535	193	1,998	1966	264	469	260	993
1946	623	1,258	494	2,375	1967	169	485	176	830
1947	469	986	769	2,224	1968	293	266	137	696
1948	943	920	3,011	4,874	1969	262	114	22	398
1949	316	429	1,644	2,390	1970	136	56	22	214
1950	694	569	700	1,963	1971	127	97	55	280
1951	305	326	642	1,273	1972	50	154	33	237
1952	265	305	574	1,144	1973	197	211	24	432
1953	235	450	46	731	1974	196	283	14	493
1954	712	234	300	1,237	1975	234	156	27	417
1955	452	462	94	1,008	1976	153	132	30	315
1956	291	528	53	872	1977	58	73	24	155
1957	1,320	333	216	1,869	1978	21	63	13	97
1958	174	227	171	572	1979	10	57	39	106
1959	227	160	216	603	1980	31	40	33	104
1960	93	212	120	425	1981	15	41	42	98
1961	277	171	102	550	1982	30	61	16	107
1962	295	343	165	803	1983	29	161	35	225

2) Non-conservative - on the basis of this analysis and previous analyses (i.e., petrale sole stock size has no bearing on year-class strength) the trip limit should be removed.

4.4. Queen Charlotte Sound

4.4.1. Rock sole

In Queen Charlotte Sound, the rock sole (Lepidopsetta bilineata) is a minor component of the shelf, on-bottom trawl fishery whose other principal members are Pacific cod (Gadus macrocephalus) and lingcod (Ophiodon elongatus). Ketchen (1982) delineated two discrete stocks, based on results of tagging experiments conducted during 1952-54 and 1960. One stock is located in Area 5A, primarily Cook Bank, and the other in Area 5B, primarily on Goose Island Bank.

Canada-U.S. standardized landing statistics of Foucher (1984) were used in the rock sole stock assessment for Areas 5A and 5B. No age composition data are available.

4.4.1.1. Introduction to Area 5A

The fishery for rock sole in Area 5A takes place on a relatively small portion of Cook Bank at shallow depths (40-50 fath).

Landing statistics are the basis for the following stock assessment.

4.4.1.2. Landing statistics

Standardized landing statistics (Foucher 1984) for rock sole in Area 5A are presented in Table 4.4.1. (Fig. 4.4.1.).

Landings, effort and LPUE for the time series all show periodic fluctuations, possibly due to recruitment, but no overall trend.

4.4.1.3. Assessment

The relationship between LPUE and effort was examined by regressing LPUE on effort. The coefficient of determination for the regression analysis was 0.01. There was also no trend in residuals. A simple plot of LPUE vs effort revealed no discernable relationship.

4.4.1.4. Conclusions

Landing statistics suggest that this population has sustained effort levels well above the current level with little change in LPUE. Effort level in 1976 was 60% higher than current levels. It is suspected that landings for rock sole in 5A reflect fluctuations in recruitment, but until age composition data is available this cannot be confirmed.

4.4.1.5. Yield options

An upper limit of 500 t is suggested as this is the highest historical yield for the fishery.

Table 4.4.1. Standardized Canada-U.S. landing statistics for rock sole from Area 5A, January-December 1956-83. (Source: Foucher 1984.)

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	551	1328	415
1957	511	1780	287
1958	501	1920	261
1959	212	1293	164
1960	397	1640	242
1961	237	1139	208
1962	196	1719	114
1963	161	1288	125
1964	156	1642	95
1965	157	1040	151
1966	330	1803	183
1967	252	1292	195
1968	435	2042	213
1969	293	2203	133
1970	167	1144	146
1971	135	1000	135
1972	58	763	76
1973	57	722	79
1974	74	1451	51
1975	37	597	62
1976	182	3309	55
1977	83	1766	47
1978	79	1129	70
1979	202	1474	137
1980	238	1384	172
1981	114	726	157
1982	189	1512	125
1983	124	1824	68

[a] Effort = (Landings)(1000)/LPUE.

[b] LPUE -- April-September.

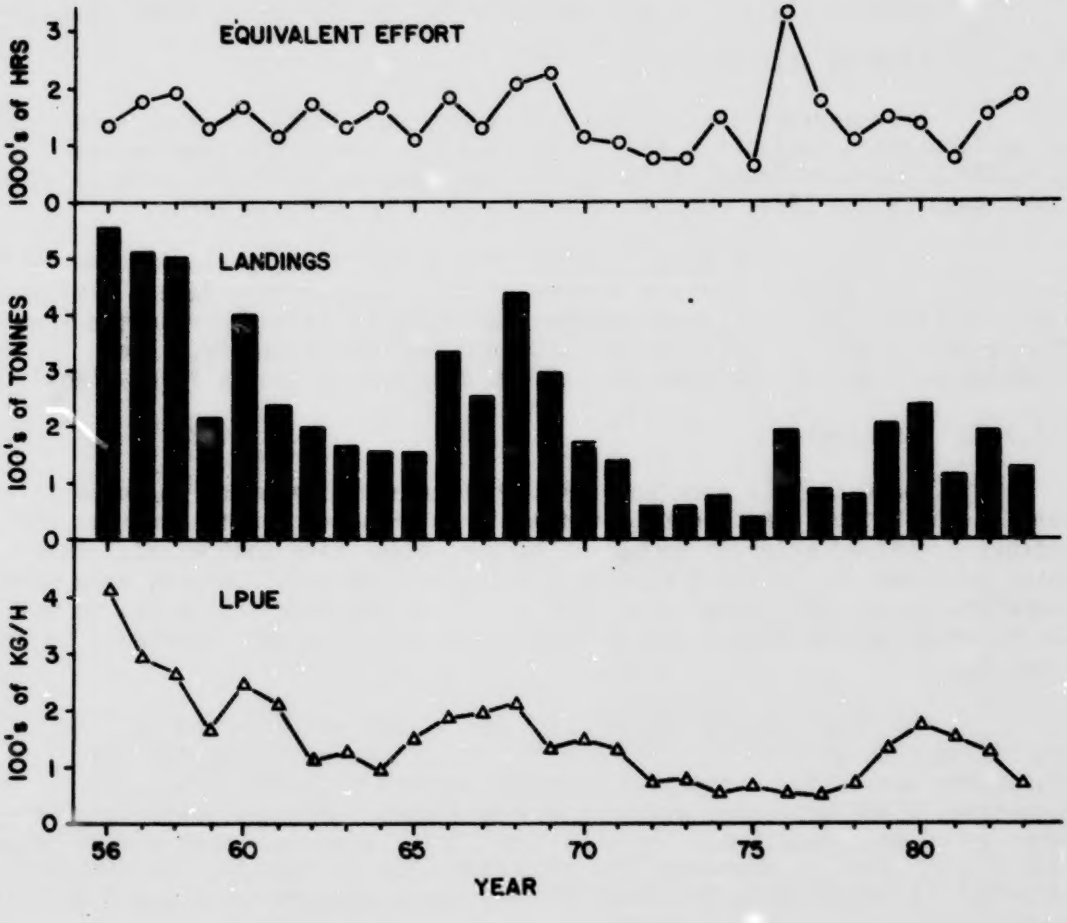


Fig. 4.4.1 Standardized Canada-U.S. landing statistics for rock sole from Area 5A, January-December 1956-84. (Source: Foucher 1984.)

4.4.1.6. Introduction to Area 5B

Fishing for rock sole (Lepidopsetta bilineata) in Area 5B takes place on a relatively small portion of Goose Island Bank at depths of 40-50 fath. As in the case of Sec. 4.4.1.1. the fishery is of a multispecies nature.

Landing statistics are the basis for the following stock assessment.

4.4.1.7. Landing statistics

Standardized landing statistics (Foucher 1984) for rock sole in Area 5B are presented in Table 4.4.2. (Fig. 4.4.2.). The LPUE time series exhibits a downward trend initially and has remained relatively stable at a lower level since 1973. One exception is the high LPUE in 1980.

It can be seen from the LPUE time series that, excluding the first few years, the highest LPUEs have been produced with effort levels similar to those in 1983. No significant increase or decrease in yield resulted from the high effort levels in 1973-76, but LPUE dropped substantially. The anomalously high LPUE in 1980 may reflect a temporary change in availability.

4.4.1.8. Assessment

The extent of rock sole distribution and migrations on Goose Island Bank is not known. Antcedotal evidence from fishermen indicates that 1980 catches contained a larger number of larger, older fish than usual. This was later confirmed by length frequency samples. It is possible that warm water temperatures in 1980 caused rock sole on top of the bank (20-30 fm) to move to cooler water on the slopes (40-50 fath), thus becoming more available to the trawl fleet.

The relationship between LPUE and effort was examined by regressing LPUE on effort. The co-efficient of determination for the regression was 0.49. A negative relation between LPUE and effort was suggested. LPUE decreases with increasing effort. All residuals for the later years were negative. The LPUE time series also indicates a much higher (2-3 times) level of abundance for rock from 1956-72 than for the time period 1973-83. It is unlikely that availability would account for a trend of long duration.

4.4.1.9. Conclusions

Without ageing data or information of species interactions in Area 5B it is difficult to assess the impact of fishing on the stock or the significance of recruitment fluctuations and changes in availability in regard to the catch/effort statistics. At present it is unclear whether the change in abundance as indicated by LPUE from 1973 is fishery induced.

4.4.1.10. Yield options

In recent years (1973-1983), excluding the year of 1980 as one of high availability, an average sustainable yield of 250 t has been calculated.

Table 4.4.2. Standardized Canada-U.S. landing statistics for rock sole from Area 5B January-December 1956-83. (Source: Foucher 1984.)

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	307	853	360
1957	206	619	333
1958	379	1606	236
1959	344	1339	257
1960	503	1863	270
1961	416	1770	235
1962	531	2091	254
1963	517	1958	264
1964	482	2472	195
1965	568	2021	281
1966	772	2339	330
1967	741	2487	298
1968	392	1774	221
1969	652	2751	237
1970	245	1161	211
1971	368	2079	177
1972	382	2748	139
1973	324	5586	58
1974	371	7275	51
1975	408	4250	96
1976	368	4182	88
1977	188	3133	60
1978	217	2932	74
1979	208	2667	78
1980	410	1925	213
1981	220	2588	85
1982	155	3039	51
1983	206	2424	85

[a] Effort = (Landings)(1000)/LPUE.

[b] LPUE -- April-September.

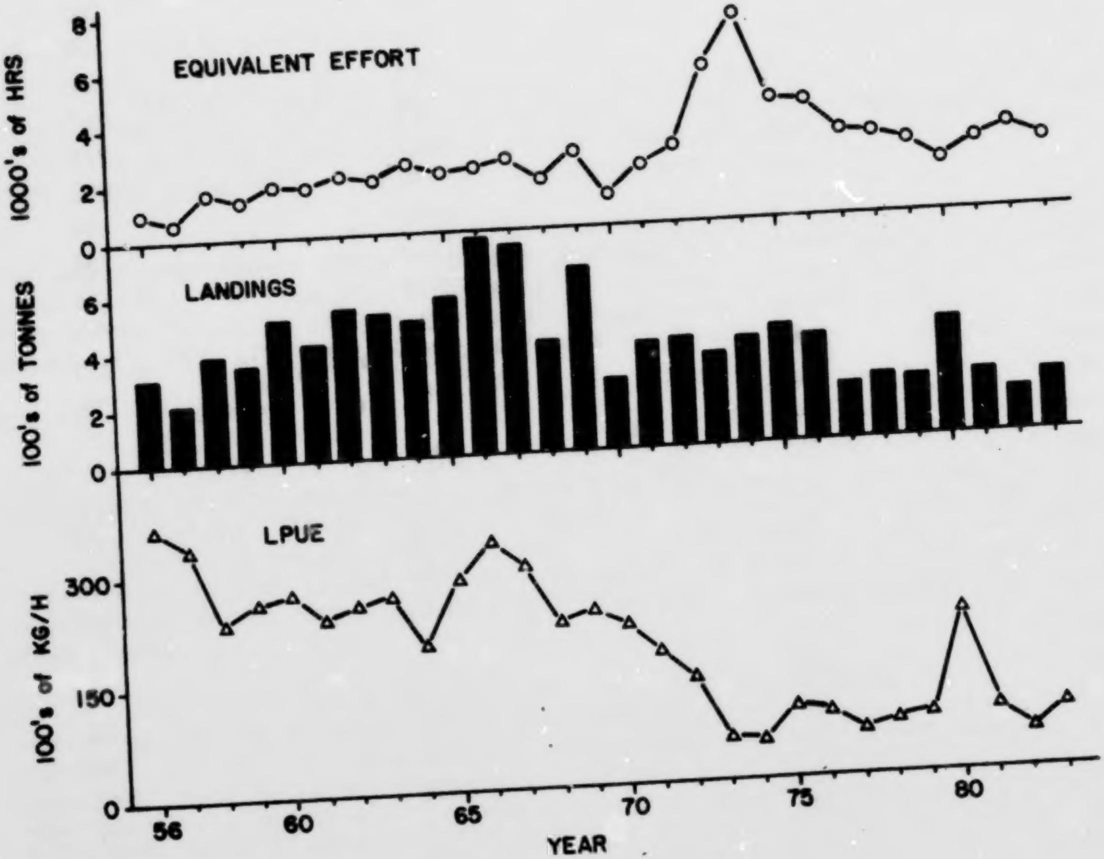


Fig. 4.4.1 Standardized Canada-U.S. landing statistics for rock sole from Area 5B, January-December, 1956-84. (Source: Foucher 1984.)

4.5. Hecate Strait

Hecate Strait - rock sole, English sole, and Dover sole are the flatfish species of commercial importance in Hecate Strait. Rock sole and English sole are minor components of multispecies fisheries while the Dover sole fishery is mainly a single species fishery.

4.5.1. Rock sole

4.5.1.1. General introduction

Rock sole (*Lepidopsetta bilineata*) in Hecate Strait is a component in a multi-species *on-bottom trawl fishery* whose other principals are English sole (*Parophrys vetulus*) and/or Pacific cod (*Gadus macrocephalus*). Two stocks *have been tentatively* acknowledged--one *in* Area *5C* and the other in Area 5D. Stock delineation is based on abundance trends in landing statistics and length-frequency anomalies, and preliminary results of the 1982 tagging experiment (Harling et al. 1982).

4.5.1.2. Introduction to Area 5C

The fishery for rock sole in Area 5C is seasonal. Approximately 84% of the landings of rock sole occur during April-September. Principal grounds are Ole Spot, Horseshoe, and Reef Island-Cumshewa. The April-May fishery is predominantly on a spawning population at Reef Island-Cumshewa while summer and fall landings come from Ole Spot and Horseshoe grounds. The fishery at Reef Island-Cumshewa in April-May was curtailed during 1981-83 due to an area closure imposed for conservation reasons.

Landing statistics and length frequency anomalies are the basis for this stock assessment.

4.5.1.3. Landing statistics

Area 5C rock sole landing statistics for 1956-83 are presented in Fig. 4.5.1. and Table 4.5.1. (Foucher 1984). Landings and effort both exhibit cyclic fluctuations with prominent peaks in 1967-69. LPUE shows similar fluctuations, at times out of phase with landings and effort. Effort, landings, and LPUE decline after 1980, primarily due to the area closure previously mentioned.

4.5.1.4. Length-frequency anomalies

Recruitment variation has been shown to have a significant effect on yield for rock sole. A time series of length frequency anomalies (Fig. 4.5.2.) for Area 5C rock sole supports this. The high landings in the late 1960s correspond to a period of positive anomalies (strong recruitment). Since 1970, recruitment has been average to below average with a brief surge in the late 1970s. Currently, recruitment is at a low level with a significant proportion of the stock consisting of older fish (ages 8-15). The percentage of older fish has remained stable over the last 7-8 years.

4.5.1.5. Assessment

The relationship between LPUE and effort was examined by regressing LPUE on effort. Coefficient of determination for this analysis was 0.13. This figure indicates the general lack of coherence in the catch/effort data.

4.5.1.6. Conclusions

No significant decline in abundance has been detected in the LPUE analysis, however, recruitment remains at a low level.

Production models applied to Area 5C rock sole (Stocker 1981) indicated a maximum sustainable yield of 500 t for the stock. This yield was to be achieved by setting a catch quota of 500 t. The catch quota resulted in supply and marketing problems for industry because the quota was reached early in the fishing season.

A separate analysis determined that over the last 25 years if trips >30,000 lb. per boat were eliminated, production for 5C rock sole would stablize near MSY levels. The trip limit could also be removed to take advantage of strong yearclasses.

4.5.1.7. Yield options

Sustainable: A trip limit of 30,000 lb. (14 t) is recommended due to the low recruitment mode for rock sole in Area 5C. This is recommended to prevent the possibility of recruitment overfishing.

Table 4.5.1.6. Standardized Canada-U.S. landing statistics for rock sole from Area 5C, January-December 1956-83. (Source: Foucher 1984.)

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	397	570	696
1957	726	1387	520
1958	368	1027	382
1959	249	1042	231
1960	471	1191	395
1961	110	312	314
1962	322	614	495
1963	155	471	344
1964	244	1166	207
1965	539	2774	131
1966	961	2697	329
1967	948	2312	484
1968	811	2154	409
1969	1053	4297	259
1970	694	2468	288
1971	376	1363	289
1972	134	612	351
1973	186	827	343
1974	288	1269	227
1975	383	2200	184
1976	277	1764	153
1977	272	1771	179
1978	356	1306	287
1979	647	2492	264
1980	482	2806	183
1981	126	2313	58
1982	70	2121	38
1983	60	1128	71

[a] Effort = (Landings)(1000)/LPUE

[b] LPUE -- April-September

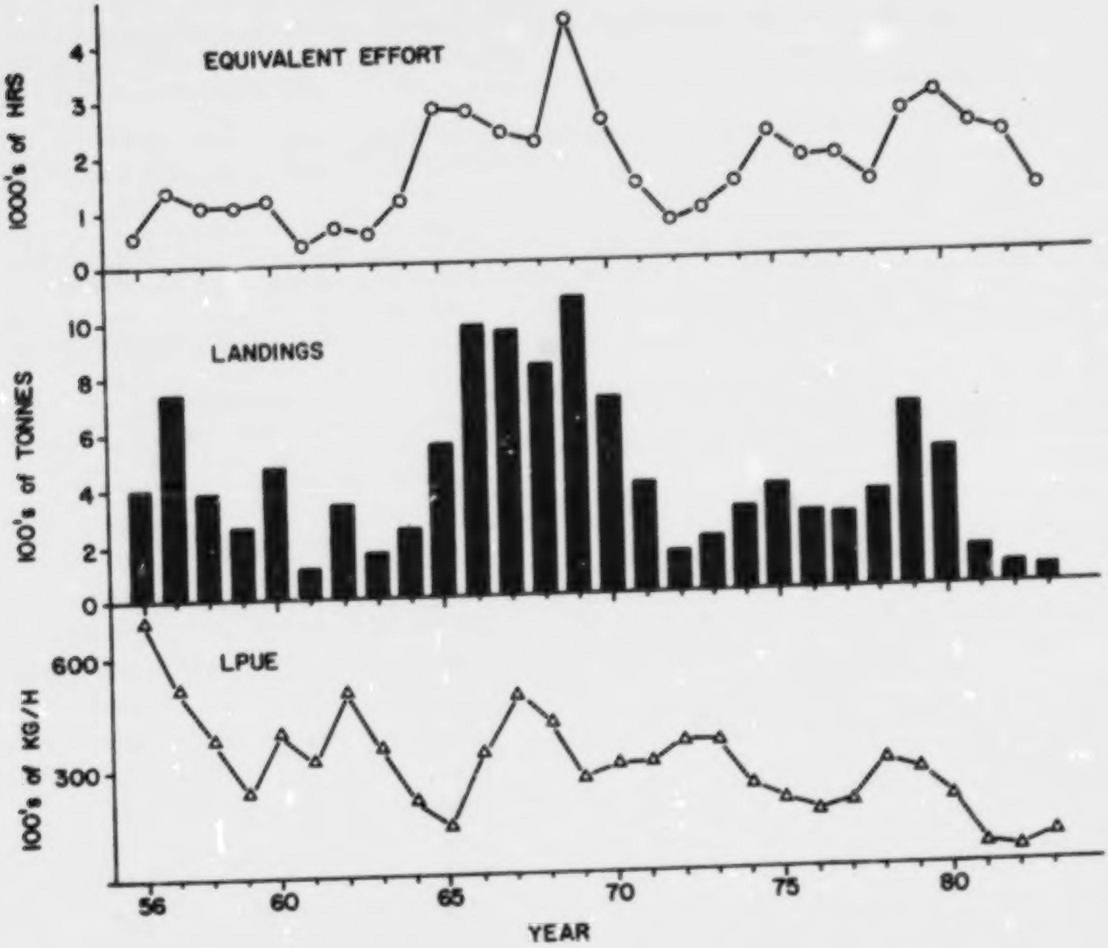


Fig. 4.5.1 Standardized Canada-U.S. landing statistics for rock sole from Area 5C, January-December 1956-84 (Source: Foucher 1984).

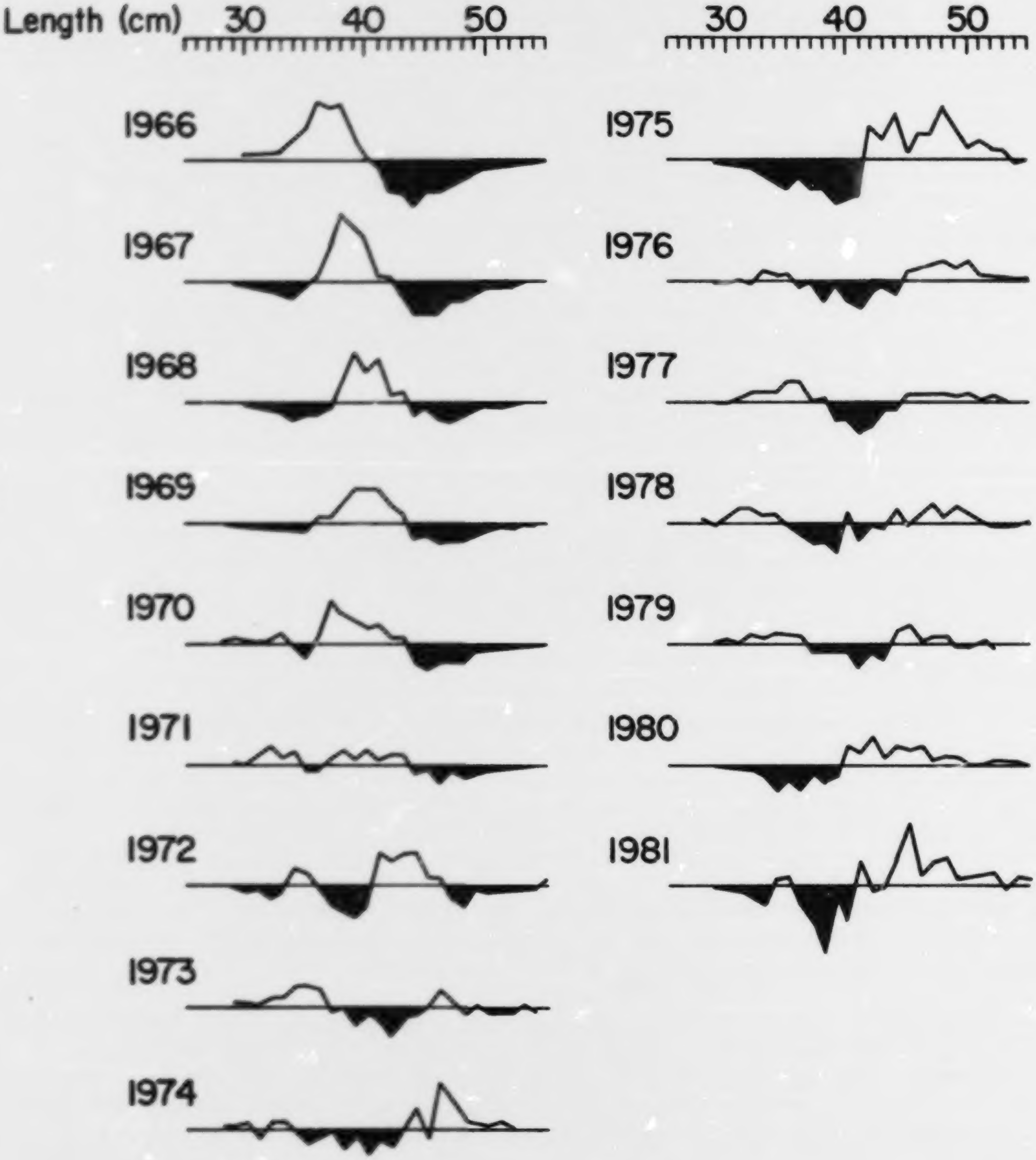


Fig. 4.5.2. Length frequency anomalies for rock sole from Area 5C (January-December) 1966-81. Samples not taken in 1982, 83.

4.5.1.8. Introduction (Area 5D)

The fishery for rock sole in Area 5D is seasonal--80% of the landings occur during the months of April-September. Principal grounds are Two Peaks-Butterworth and Shell. Catches of rock sole by the U.S. fleet operating in Area 5D were mostly discarded due to poor market conditions. Since 1970, Canadian fishermen have discovered that catch rates are usually substantially higher at night. The extent of night fishing in the landing statistics is unknown, because effort is not reported by time of day.

Landing statistics, length frequency anomalies, age composition data, and a stock-recruit model are the basis for the following assessment.

4.5.1.9. Landing statistics

Standardized landing statistics (Foucher 1984) for rock sole in Area 5D during 1956-83 are presented in Figure 4.5.3. and Table 4.5.2. Landings have fluctuated throughout the period with peaks occurring during 1966-69. Effort shows an upward trend over the time series with a substantial (2-3 times) increase during 1977-81. LPUE exhibits a declining trend over the same period with the lowest LPUEs during 1977-81.

4.5.1.10. Length-frequency anomalies

Major periods of production for rock sole in Area 5D in the late 1960s and 1970s coincide with positive anomalies (strong recruitment) (Fig. 4.5.5.). Indices of recruitment derived from cohort analysis also agree fairly well with length-frequency anomalies.

4.5.1.11. Assessment

Changes in real abundance of rock sole are related partly to recruitment fluctuations which can vary by an order of magnitude. There is a bias introduced into the LPUE statistic by the "learning" effect of night fishing in the later years. Results of regression analysis indicate that 50% of the variation in rock sole LPUE (abundance) in this set of landing statistics can be accounted for by Pacific cod landings. Both of these items would cause results of analysis of LPUE and effort to be unreliable. Results of cohort analysis are therefore favoured over analysis of LPUE. The results of cohort analysis indicate a peak in stock size in 1958 and 1959, and another in 1965, 1966, and 1967 (Fig. 4.5.4.).

In the previous stock assessment document (Stocker (ed.) 1981) for the purpose of VPA and yield simulations, the instantaneous rate of natural mortality (M) for rock sole was assumed to be 0.15 with $q=2.4 \times 10^{-4}$. Using the new standardized effort time series and Paloheimo's (1980) method, M has been estimated at 0.21 and the catchability coefficient (q) was estimated at 8.37×10^{-5}.

Yield simulations (Walters 1969) were done for rock sole in Area 5D for the time period 1954-78 using parameters published in Stocker (1981) and also using new estimates of M and q with results of a separate cohort analysis. Residuals for predicted and observed values for the simulation using the original parameter estimates showed a negative bias (predicted yields too low) possibly because of lack of effort standardization. Residuals for the simulation using the new parameter estimates showed no bias but yields for 1972-78 were overestimated. This may be due to an overestimation of effective fishing effort on the species in later years. If this is true, the LPUE index in recent years, for example the 1980's, may be much too low.

Understanding the stock-recruit relationship for the species is of primary importance in determining optimum stock levels and yield for the species. A simple graph for rock sole in Area 5D relating temperature to year-class strength was presented in Ketchen (1980a). Sea surface temperatures at Triple Island in March were plotted against rock sole year-class strengths for year-classes 1946-69. A dome-shaped relationship resulted.

Recent investigations, employing non-linear fitting procedures (Schnute and McKinnell 1984) developed a model incorporating 2 independent variables (stock size and temperature) on the dependent variable year-class strength (MS in prep.). Relative stock size was calculated as the sum of the LPUE-at-age for ages 4 through 10. The three-dimensional model accounted for 60% of the variation in rock sole year-class strengths for the 1946-69 year classes. The trend in year-class strength for 1946-69 was captured fairly well by the model (Fig. 4.5.6.).

The response surface from the model (Fig. 4.5.7.) indicates a Beverton-Holt S-R relationship for the stock with little change in production for the stock at low and high levels. The surface also indicates a "critical" level for stock size, below which production drops rapidly. The 1969 year class was produced from a spawning biomass near the critical level. From cohort analysis the stock had 5 million females at ages 4 through 13 at this time. For stock sizes above the "critical" level, temperature is the major determinant of year-class strength. The critical level is independent of temperature.

The length frequency anomalies (Fig. 4.5.5.) indicate that recruitment to the fishery was average during 1977, 1978, and 1979 with an above average year-class entering the fishery in 1980. Warm ocean water since that time has probably precluded the development of new strong year-classes, as borne out by the 1983 length frequency sample and the annual flatfish juvenile survey (unpublished data). Because fishing effort has been reduced (Fig. 4.5.3.) however, the stock is likely not in danger of being pushed below the critical level of 5 million mature females. Considering the stock-size estimates from cohort analysis from the late 70's, and the recent recruitment pattern, we suggest that the stock size is about the same level as during the late 60's, and slightly above the critical level.

4.5.1.12. Conclusions

The response surface analysis indicates that maintenance of a minimum stock size is important to recruitment for rock sole in Area 5D. Managing for maintenance of a large stock size appears to be unnecessary.

In the late 1960s, the stock size for rock sole in Area 5D fell below the level indicated by the model for optimum production. The LPUE time series shows a decline since that time, while the yield simulations indicate that actual LPUE may be higher for the later years than estimated. The present population is estimated to be slightly higher than in the late 1960's.

In the previous stock assessment document, a yield of 250 t was estimated for rock sole in Area 5D (Stocker 1981). A separate analysis determined that a 30,000 lb. trip limit for rock sole in Hecate Strait would help to achieve this.

4.5.1.13. Yield options

Rebuilding: It is difficult to evaluate the effects of the trip limit on rock sole production in Area 5D, but in 1981 the 250 t level previously mentioned was exceeded. A more conservative trip limit of 20,000 lb. would help to prevent this, but would also curtail rock sole production in Area 5C.

Sustainable: The 30,000 lb. (14 t) trip limit will help to keep Area 5D rock sole stock size above the "critical" level.

Table 4.5.2. Standardized Canada-U.S. landing statistics for rock sole from Area 5D, January-December 1956-83. (Source: Foucher 1984.)

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	763	1538	496
1957	425	2361	180
1958	888	742	1197
1959	167	1099	152
1960	656	989	663
1961	634	402	1578
1962	507	754	672
1963	726	1287	564
1964	499	1102	453
1965	340	1255	271
1966	1583	3244	488
1967	1214	918	1323
1968	1555	3337	466
1969	1356	2122	639
1970	709	1672	424
1971	1127	2466	457
1972	381	2268	168
1973	321	2568	125
1974	334	2212	151
1975	821	5864	140
1976	1161	5609	207
1977	574	8085	71
1978	518	3453	150
1979	666	11288	59
1980	495	7174	69
1981	458	8035	57
1982	221	3508	63
1983	187	2922	64

[a] Effort = (Landings)(1000)/LPUE.

[b] LPUE -- Two Peaks-Butterworth, April-September.

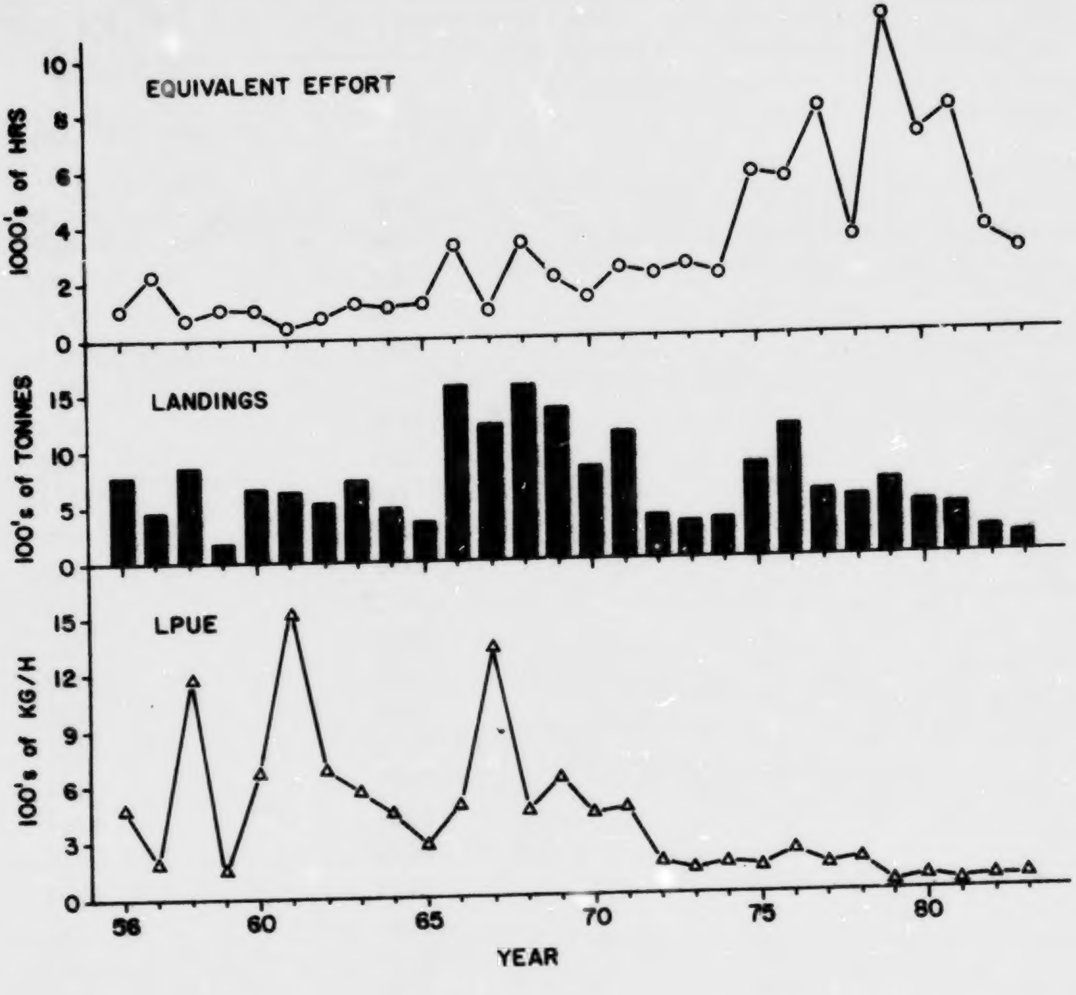


Fig. 4.5.3. Standardized Canada-U.S. landing statistics for rock sole from Area 5D, Januar-December 1956-84. (Source: Foucher 1984).

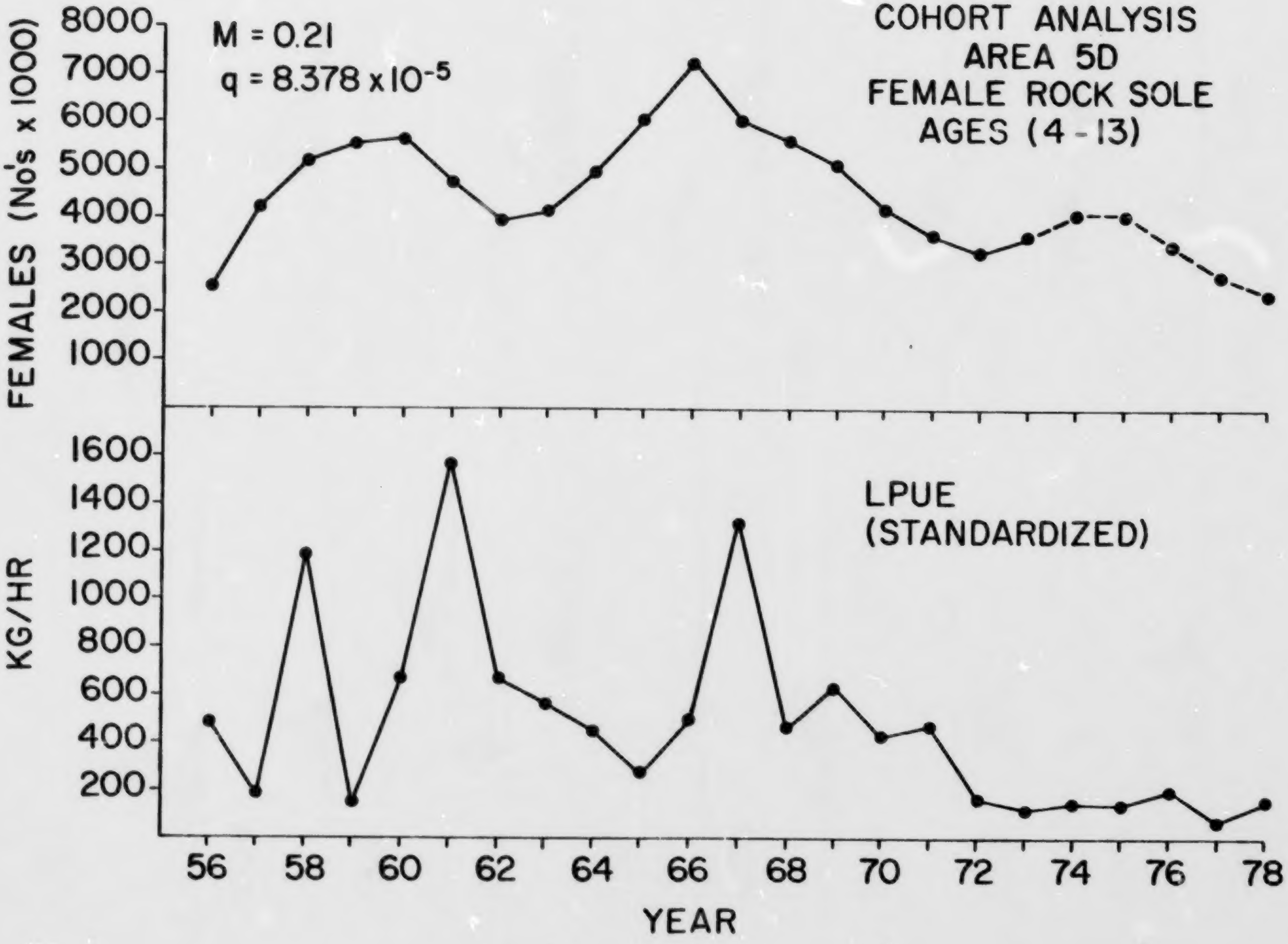


Fig. 4.5.4. Rock sole Area 5D cohort analysis and LPUE time series 1956-78. Dashed line in cohort analysis is where cumulative fishing mortality is greater than 2.0.

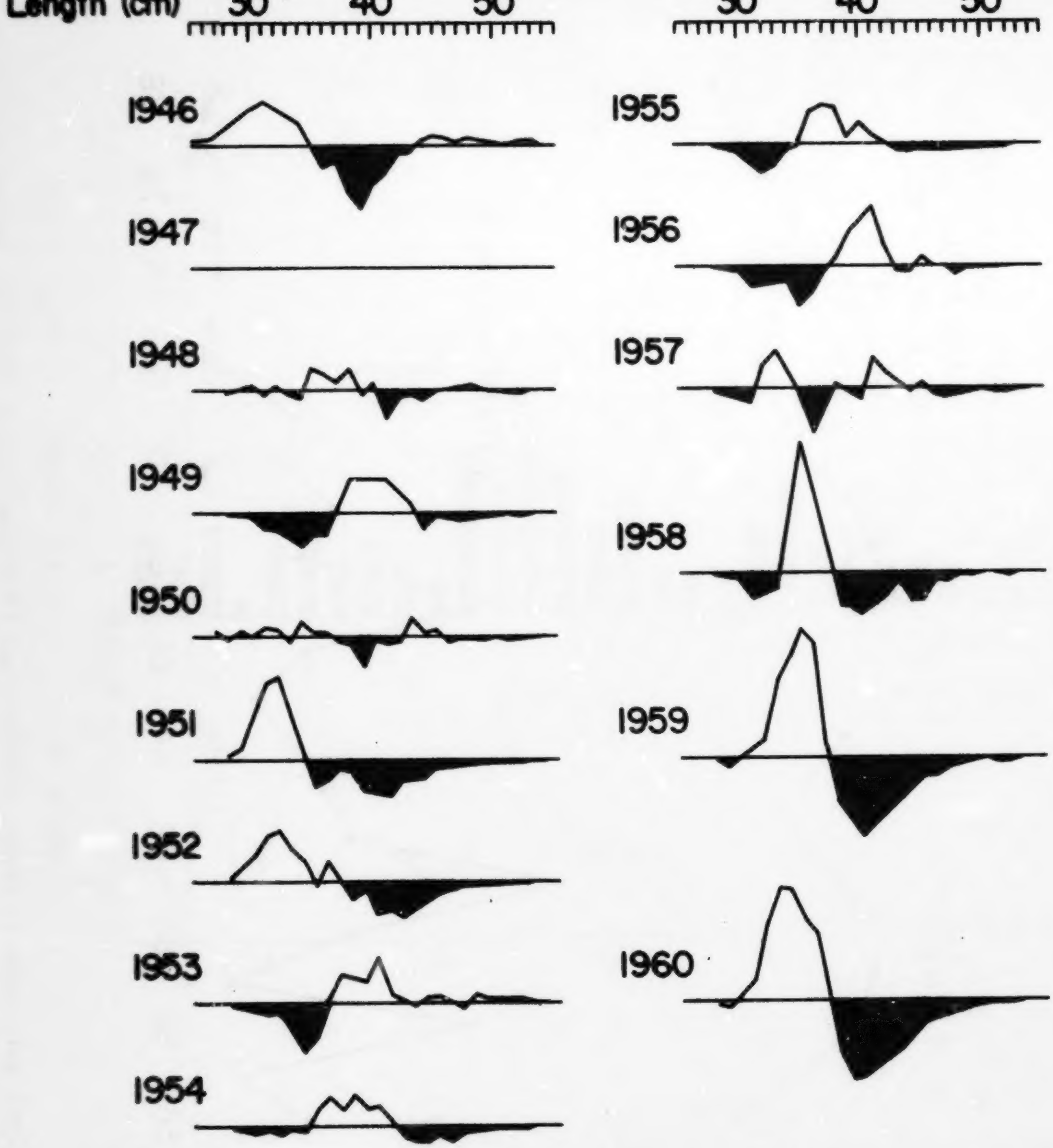


Fig. 4.5.5. Length frequency anomalies for rock sole from Butterworth-Two Peaks grounds (April-Septmebr) 1976-83. Samples not taken in 1947, 72, 81, 82.

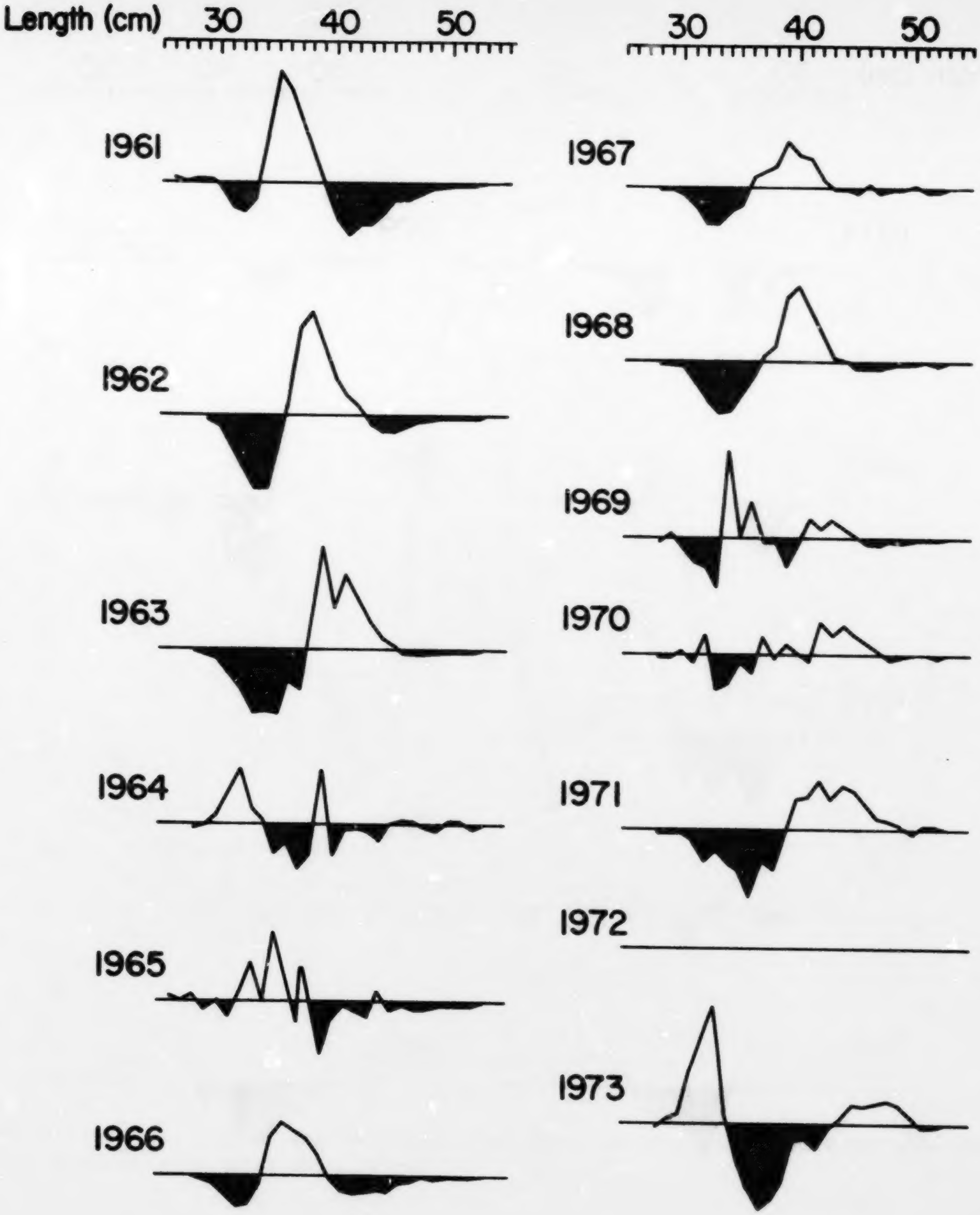
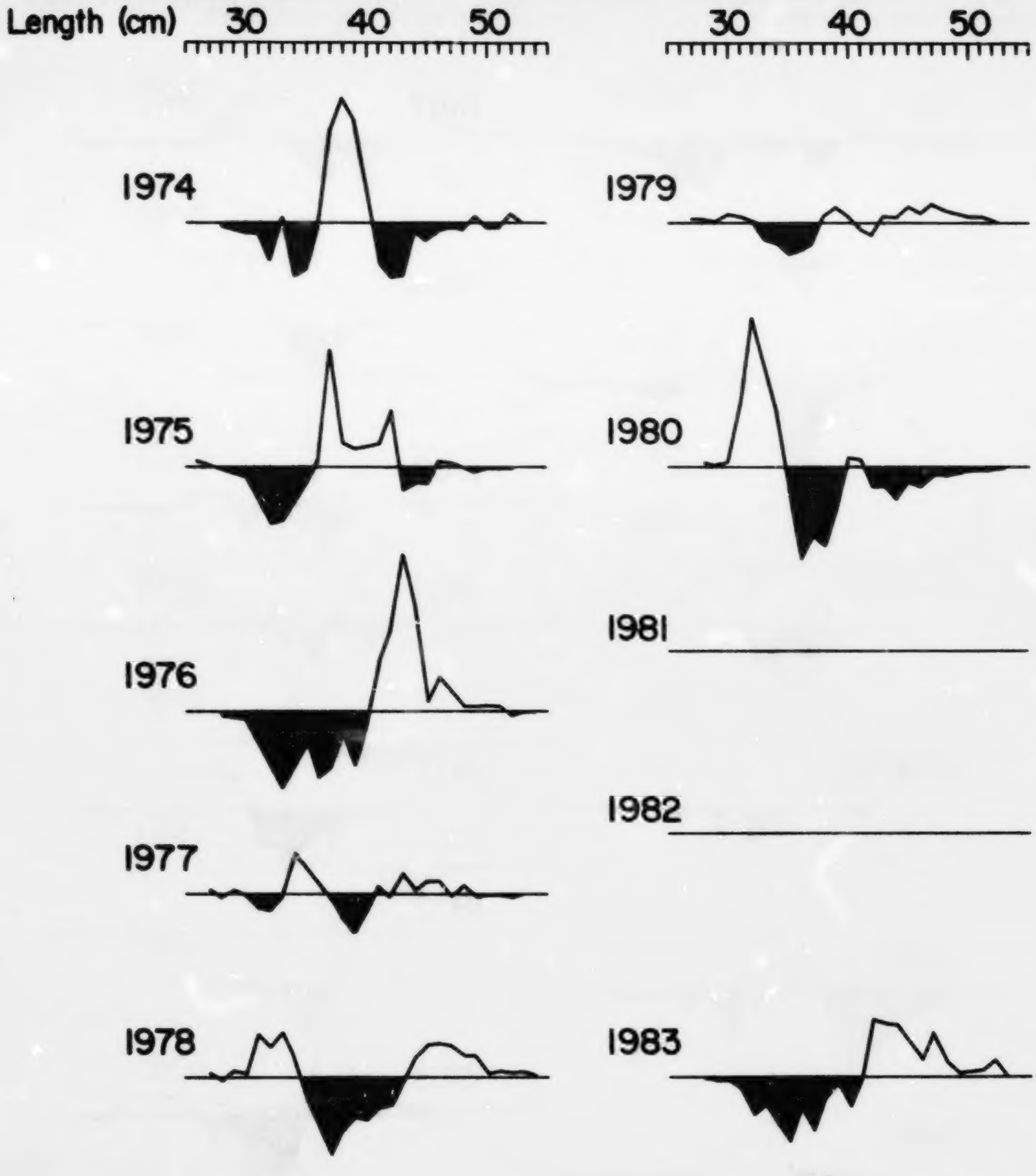


Fig. 4.5.5. (Continued)



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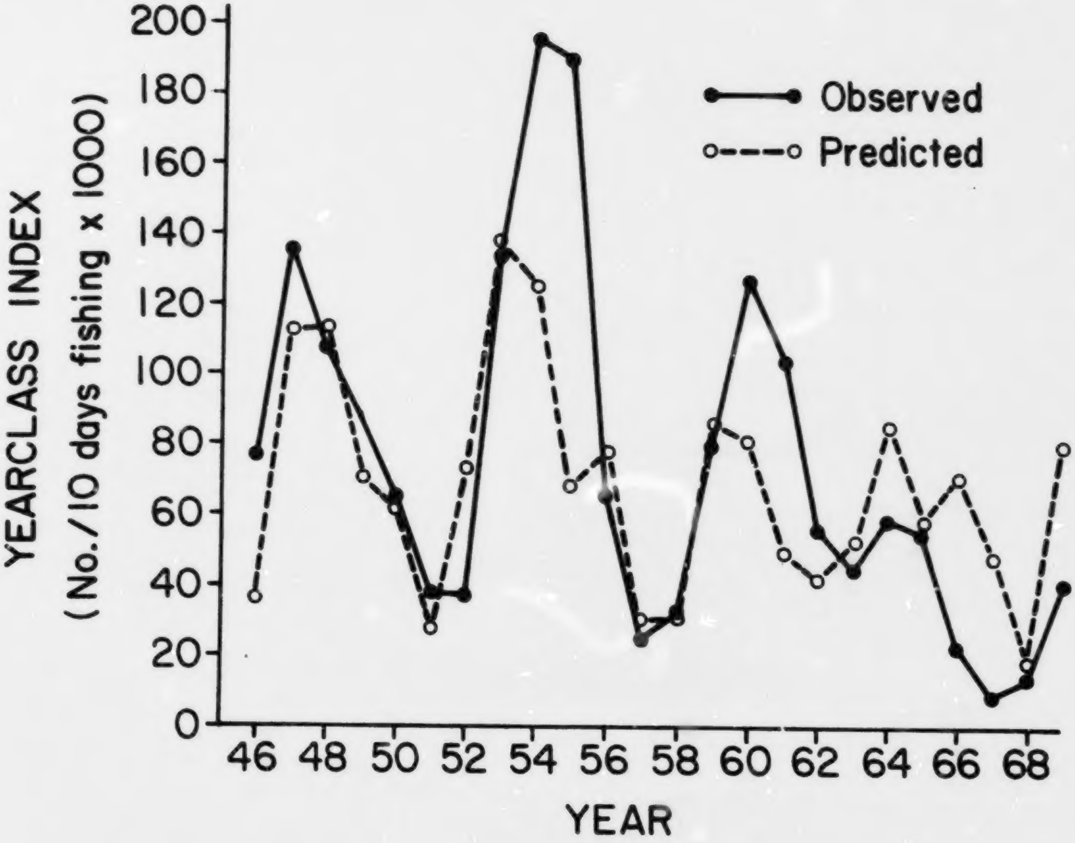


Fig. 4.5.6. Time series trends for observed and predicted rock sole year-class strengths in Area 5D, 1946-69.

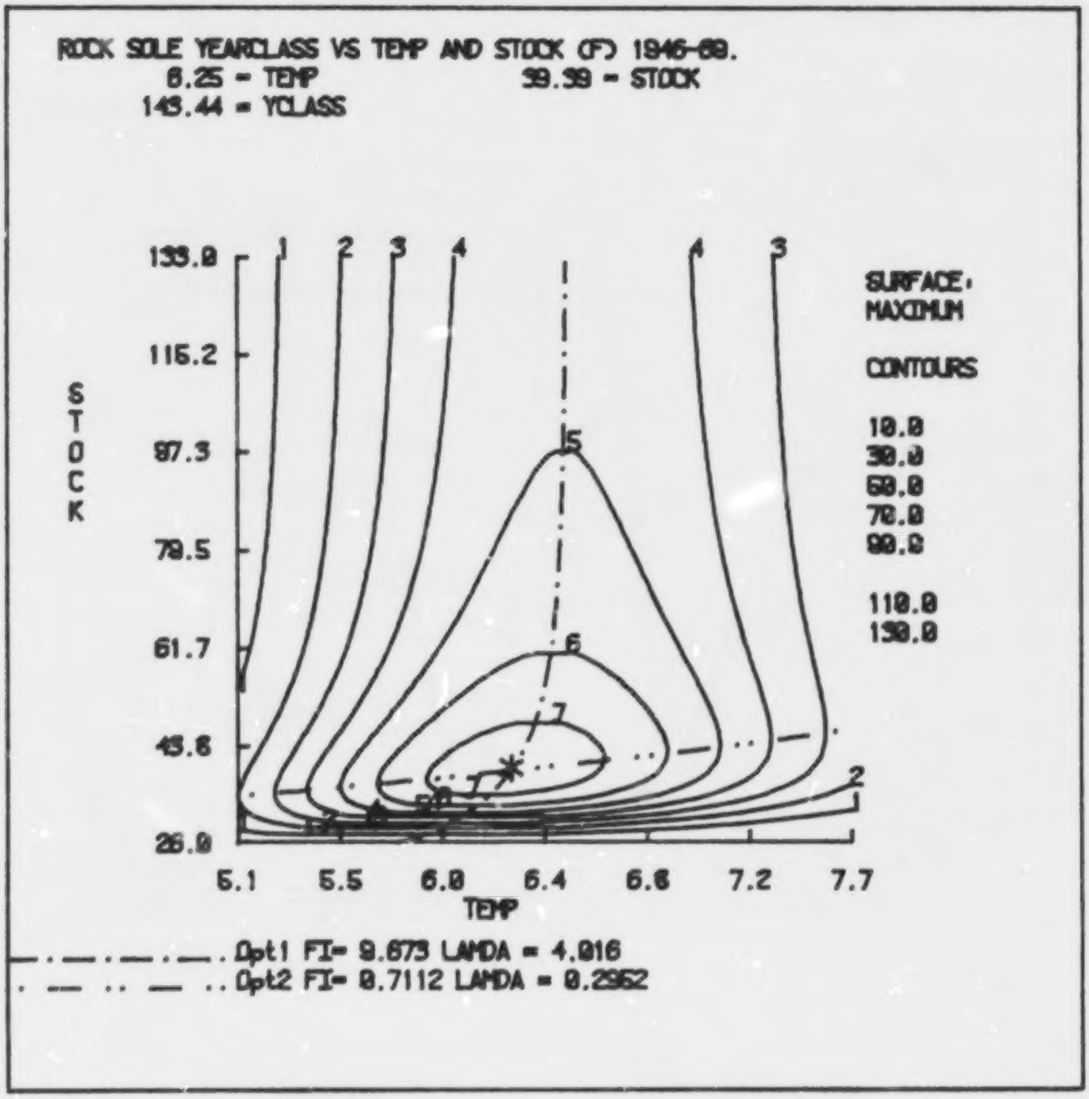


Fig. 4.5.7. Response surface for Area 5D rock sole year-class strength vs temperature and stock size. Opt. 1 represents the optimum year-class strength at fixed levels of temperature. Opt. 2 represents the optimum year-class strength for fixed levels of stock size.

4.5.2. English sole

4.5.2.1. Introduction

Hecate Strait contains the only substantial fishery for English sole (Parophrys vetulus) in British Columbia waters--in Area 5D. The principal fishing ground is Two Peaks-Butterworth (April-September), and the secondary ground is White Rocks-Bonilla (October-March). Hecate Strait is presumed to contain a single stock of English sole, on the basis of landing statistics and tagging experiments (Ketchen 1953).

The majority of the commercial fishery (~75%) involves females from 4-10 years of age, though a significant number of undersize (3-year-old) fish may be discarded in the commercial fishery. Recruitment fluctuations of 8:1 have been observed for Area 5D during 1955-79. Ketchen (1956) reported an inverse relationship between sea surface temperatures and English sole year-class abundance, but a strong stock-recruit relationship for the species has not been determined.

Landing statistics, length frequency anomalies, and age composition data form the basis for this stock assessment.

4.5.2.2. Landing statistics

Standardized landing statistics (Foucher 1984) for English sole in Area 5D for 1956-83 are presented in Figure 4.5.8. and Table 4.5.3. Landings have fluctuated throughout the entire period, and have averaged about 650 t annually. Effort has also fluctuated, sometimes out of phase with landings. A major peak in fishing effort occurred during 1977-81. Effort level was low in 1982-83. LPUE shows moderate fluctuations, but was relatively stable during 1977-83.

4.5.2.3. Length frequency anomalies

Positive length frequency anomalies (strong recruitment) (Fig. 4.5.9.) coincide with major peaks of landings in 1960, 1970, 1977, and 1981 (Fig. 4.5.8.). Strong corresponding positive anomalies during 1961-69 are not reflected in the landings, which actually decline. During this period, cod landings were increasing rapidly, and evidence from cohort analysis (Sec. 4.5.2.4) supports anecdotes from fishermen that marketable English sole were discarded at sea to facilitate retaining the large catches of cod, particularly during 1964-67. Anomalies after 1981 are probably underestimates of recuitment for those years because fish companies increased the minimum size limit for English sole in 1982

4.5.2.4. Assessment

The relationship between LPUE and effort was examined by regressing LPUE on effort. The coefficient of determination was 0.30. Changing catchabilities, availability, marketing problems, and multispecies problems, all contribute to the lack of coherence in the catch/effort data.

Instantaneous natural mortality rate (M = 0.22) and catchability coefficient (q = 1.83 E-04) were estimated for female English sole (surface

Differences in maximum yield between runs were minimal. Changing the value of M did, however, alter the fishing rate at which maximum yield was achieved. A maximum yield of 400 g/recruit was achieved at a fishing rate (F) of 0.4 for M = 0.22, 0.8 for M = 0.30, and 1.5 for M = 0.38. The fishing rate for English sole in 1983 is estimated at 0.4-0.5 F=(1.83 x 10^{-4})(1983 effort).

4.5.2.5. Conclusions

While the landing statistics indicate that English sole in Area 5D sustained a substantial amount of effort during 1977-81, length frequency anomalies and age composition data indicate the population is relatively stable. For example an above average year-class was produced in 1977 (1981 recruits) and the percentage of older fish in the population has remained fairly constant

In the past, catch quotas set for English sole in Area 5D have been exceeded (almost doubled in 1981) because the species is taken mostly incidentally in a fishery where the major species (Pacific cod) harvest is not restricted.

Currently, the English sole population in Area 5D appears stable, though cohort analysis results indicate that the stock is currently lower than MSY levels (-75% of MSY).

4.5.2.6. Yield options

Sustainable: 600 t. - equivalent to maximum yield for stock at 75% of MSY levels.

High risk: 800t. - equivalent to the long-term sustainable yield for English sole in Area 5D.

Table 4.5.3. Standardized Canada-U.S. landing statistics for English sole from Area 5D, January-December 1956-83. (Source: Foucher 1984.)

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	935	1227	762
1957	539	1437	375
1958	674	2167	311
1959	901	2944	306
1960	1079	1135	950
1961	865	1813	477
1962	436	1041	419
1963	369	1836	201
1964	420	925	454
1965	391	1498	261
1966	329	4569	72
1967	511	1175	435
1968	632	3241	195
1969	725	2245	323
1970	920	2266	406
1971	482	2060	234
1972	356	1703	209
1973	598	1420	421
1974	459	941	488
1975	922	1889	488
1976	946	3343	283
1977	972	5170	188
1978	495	3837	129
1979	744	4769	156
1980	796	4914	162
1981	1148	5600	205
1982	401	2373	169
1983	396	2522	157

[a] Effort = (Landings)(1000)/LPUE.

[b] LPUE -- Two Peaks-Butterworth, April-September.

Table 4.5.4. Hecate Strait English sole females, Area 5D, 1955-79 (Standardized effort). Cohort analysis results ($M = 0.22$, $q = 1.83 \times 10^{-4}$).

	Age									
Year	3	4	5	6	7	8	9	10	11	12
1955	2632	2820	1589	863	624	273	132	53	80	25
1956	2343	2089	1944	933	485	367	115	45	13	55
1957	2204	1866	1490	1032	477	252	220	63	26	0
1958	2266	1758	1348	1073	615	274	153	156	31	10
1959	2341	1814	1316	872	684	312	137	81	96	16
1960	1829	1871	1242	673	406	368	138	51	37	59
1961	1242	1435	1188	568	223	124	73	38	13	16
1962	1706	995	915	387	187	59	40	23	14	0
1963	2057	1365	684	476	177	71	23	22	9	8
1964	2560	1644	1013	394	203	81	32	11	13	7
1965	4229	2040	1129	569	202	105	40	21	5	9
1966	1737	3393	1555	701	301	77	45	15	7	2
1967	974	1393	2652	1077	409	162	27	22	6	6
1968	818	780	1070	1788	600	225	83	2	10	0
1969	1255	648	603	717	1036	295	102	37	0	7
1970	1663	982	459	389	406	519	122	45	18	0
1971	1955	1294	600	241	211	166	231	37	14	11
1972	2114	1542	820	363	151	126	86	128	8	4
1973	2432	1623	1099	534	239	91	73	39	90	0
1974	1964	1823	1141	688	340	153	44	32	17	63
1975	1184	1522	1311	780	458	206	94	16	20	8
1976	837	919	977	710	374	191	76	23	6	7
1977	594	660	622	444	296	122	65	11	9	2
1978	532	395	323	215	155	111	42	19	3	0
1979	1260	402	249	153	109	79	53	8	9	2

Table 4.5.5. Fishing mortality (F) for female English sole in Area 5D, 1955-78.

	Age								
Year	3	4	5	6	7	8	9	10	Mean F
1955	0.011	0.152	0.313	0.355	0.311	0.648	0.848	1.146	0.473
1956	0.008	0.118	0.413	0.452	0.436	0.292	0.383	0.345	0.306
1957	0.006	0.105	0.109	0.297	0.333	0.277	0.123	0.490	0.218
1958	0.002	0.069	0.216	0.230	0.457	0.477	0.425	0.267	0.268
1959	0.004	0.159	0.450	0.545	0.400	0.601	0.774	0.553	0.436
1960	0.023	0.234	0.562	0.883	0.962	1.396	1.054	1.103	0.777
1961	0.002	0.230	0.901	0.892	1.108	0.914	0.923	0.783	0.719
1962	0.003	0.154	0.432	0.562	0.741	0.733	0.362	0.738	0.466
1963	0.004	0.078	0.332	0.633	0.562	0.593	0.488	0.353	0.380
1964	0.007	0.156	0.357	0.450	0.437	0.480	0.192	0.672	0.344
1965	0.0003	0.052	0.256	0.415	0.742	0.635	0.788	0.857	0.468
1966	0.001	0.026	0.148	0.319	0.401	0.813	0.503	0.740	0.369
1967	0.002	0.043	0.174	0.364	0.377	0.489	2.280	0.519	0.531
1968	0.012	0.038	0.180	0.327	0.493	0.570	0.577	0.500	0.337
1969	0.025	0.126	0.217	0.350	0.471	0.665	0.604	0.532	0.374
1970	0.031	0.274	0.421	0.392	0.675	0.589	0.970	0.947	0.537
1971	0.017	0.235	0.282	0.249	0.297	0.437	0.367	1.329	0.402
1972	0.044	0.119	0.208	0.199	0.286	0.318	0.572	0.139	0.236
1973	0.068	0.132	0.249	0.233	0.223	0.513	0.625	0.602	0.331
1974	0.035	0.110	0.161	0.187	0.280	0.263	0.805	0.237	0.260
1975	0.033	0.223	0.395	0.514	0.652	0.774	1.181	0.824	0.575
1976	0.017	0.171	0.568	0.652	0.896	0.862	1.728	0.732	0.703
1977	0.187	0.496	0.843	0.832	0.765	0.853	0.982	0.925	0.735
1978	0.058	0.243	0.530	0.457	0.453	0.526	1.496	0.506	0.534

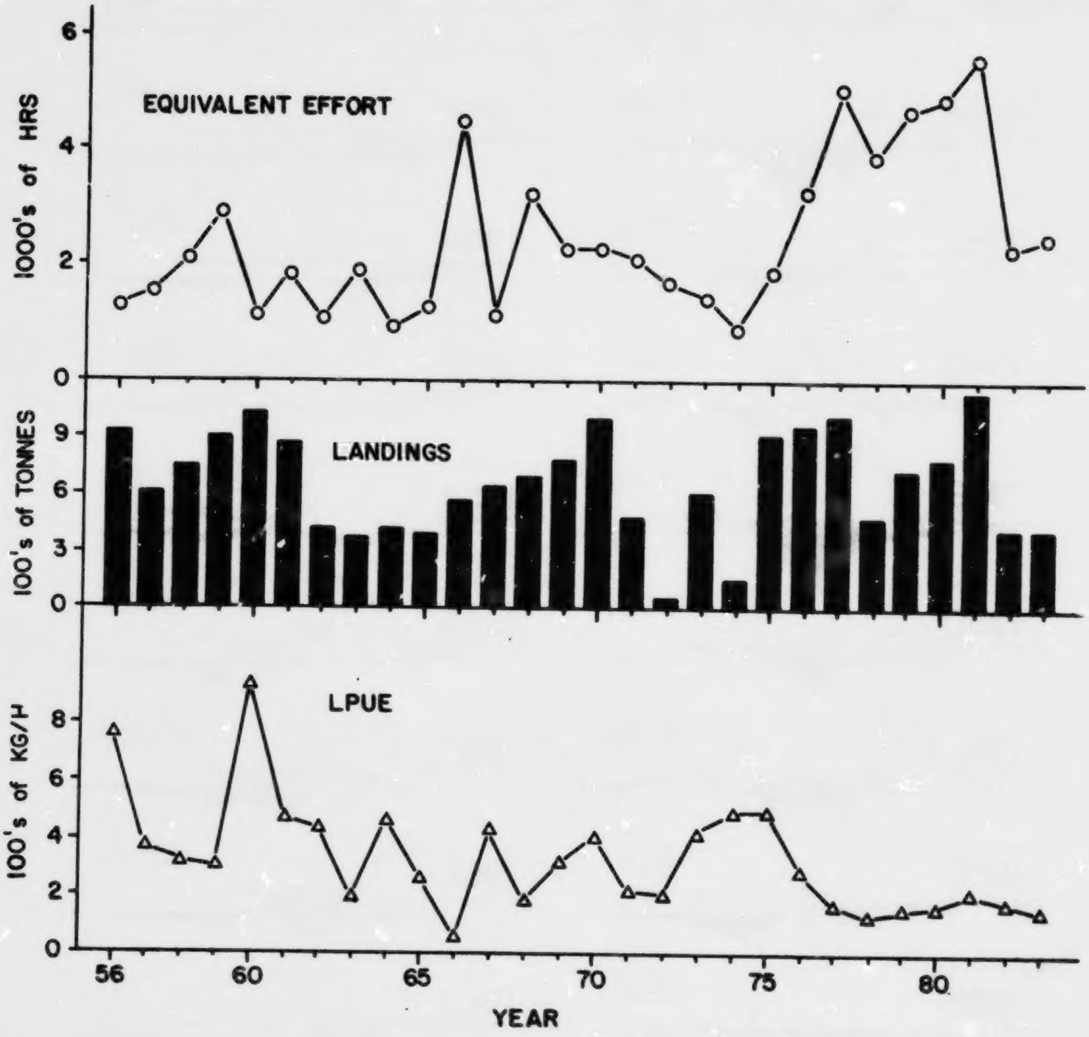


Fig. 4.5.8.Standardized Canada-U.S. landing statistics for English sole from Area 5D, January-December 1956-84. (Source: Foucher 1984.)

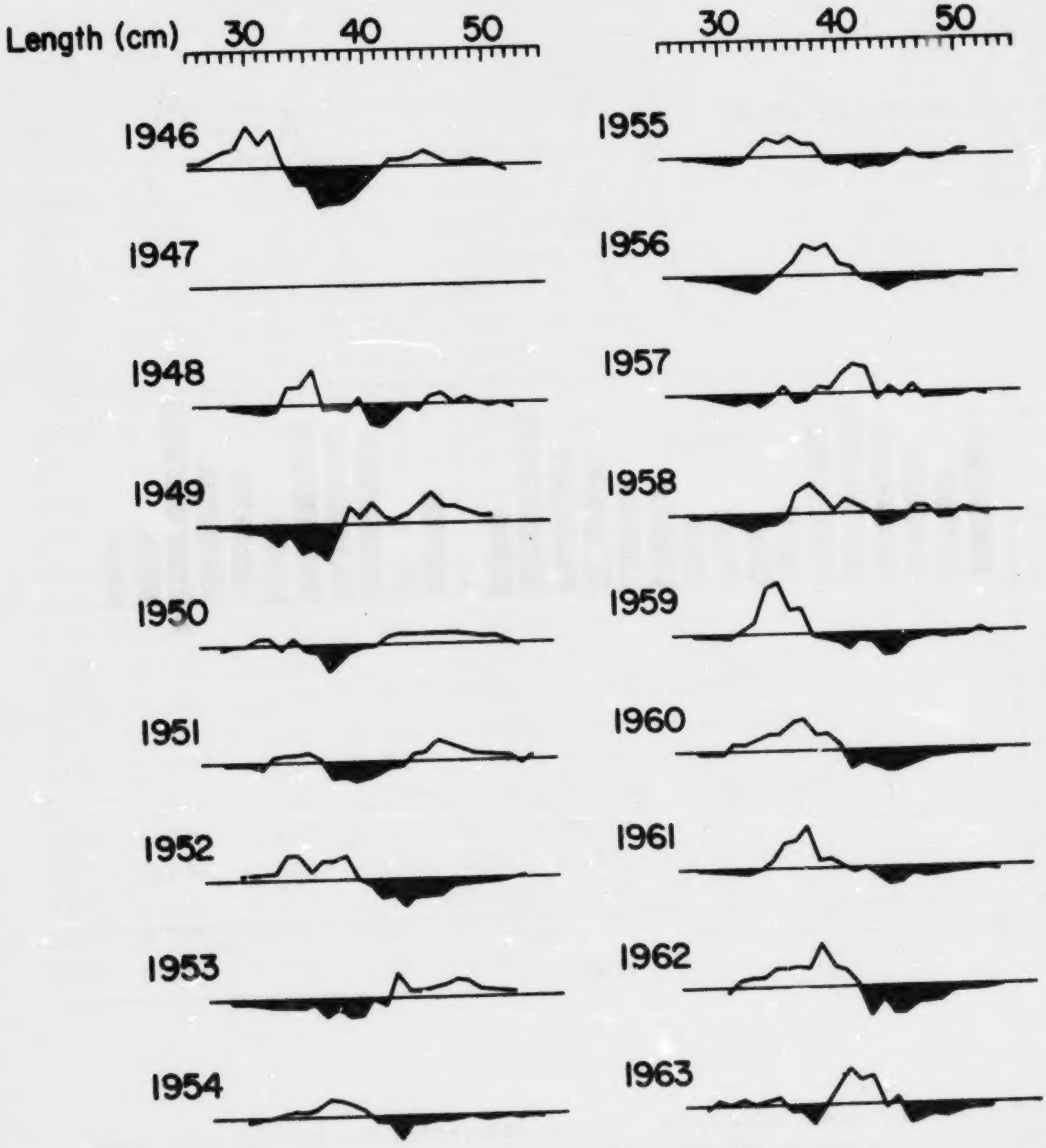


Fig. 4.5.9. Length frequency anomalies for English sole from Butterworth-Two Peaks grounds (April-September) 1946-83. Samples not taken in 1947, 72.

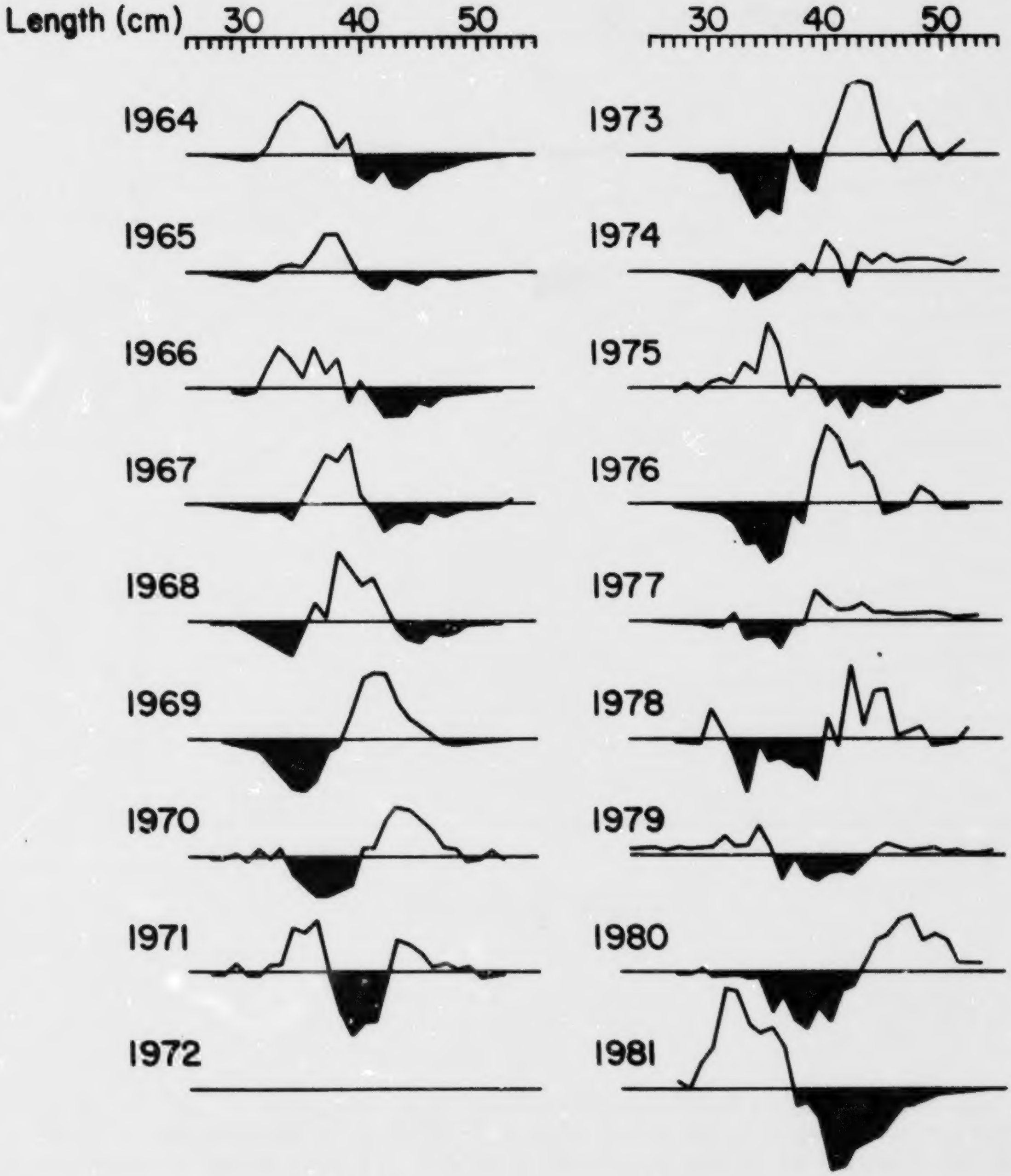
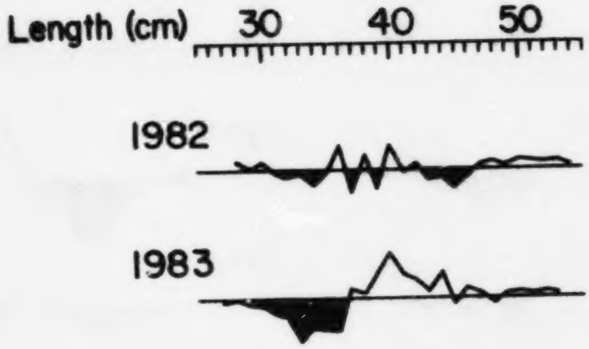


Fig. 4.5.9. (Continued)



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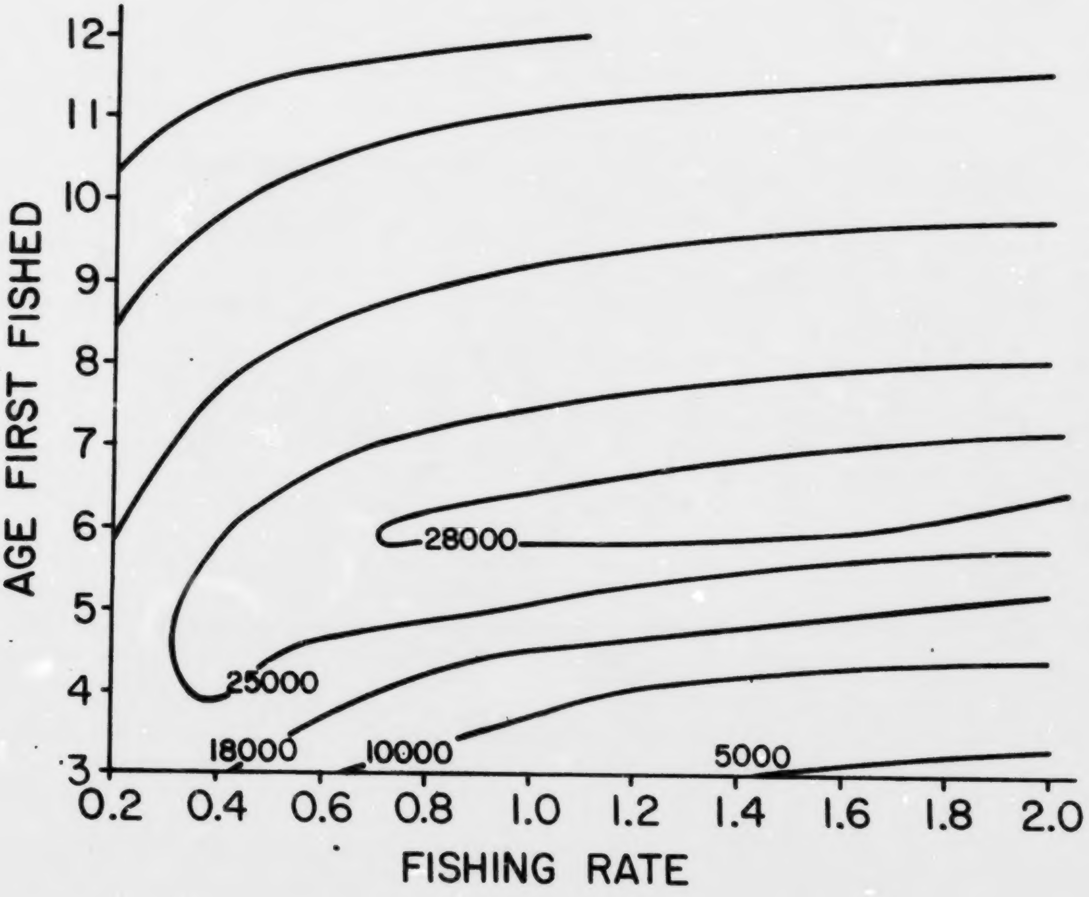

Fig. 4.5.10. Potential yield isopleths from 50-yr forward simulations for English sole females in Area 5D. Numbers in the body of the graph are tons of productions summed over 50 years in relations to age of recruitment and fishing rate.

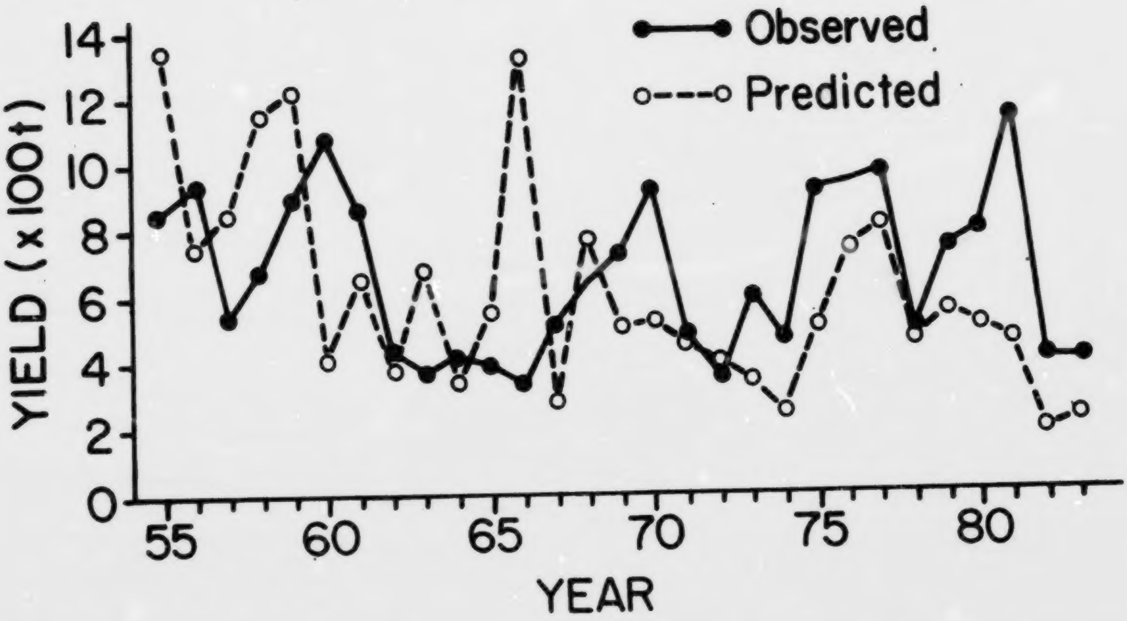

Fig. 4.5.11. Time series trends in yield for English sole in Area 5D predicted by simulation model vs trends in observed yield, 1955-83.

4.5.3. Dover sole

4.5.3.1. Introduction

In contrast to other commercially important flatfishes in Hecate Strait, Dover sole are characterized by slower growth and longer lifespan (≈40 yr). Winter migrations to deep water (5E) for spawning take place and juveniles are not significantly exposed to the commercial fishery. The magnitude of recruitment fluctuations observed for the species off Oregon (Hayman et al. 1980) is considerably less than that observed for English sole and rock sole in Hecate Strait.

The fishery for Dover sole in Hecate Strait takes place mainly during the months April-September. The principal fishing ground is Dundas, and secondary grounds are Two Peaks and Butterworth. The Dover sole fishery on Dundas Ground is mainly a single-species fishery, while that on Two Peaks-Butterworth is multi-species. The fishery has been important only since 1970 due to marketing problems for the species.

In the late 1970s, following IDP exploratory surveys (Harling et al., 1977 and Harling et al. 1978), a deepwater fishery for Dover sole developed off the west coast of the Queen Charlotte Islands. Preliminary analysis of results of a tagging project undertaken in 1979 (Stocker et al. 1980) suggests that a single stock of Dover sole occupies Areas 5C, D, E--at least the shelf portion thereof.

Landing statistics are used as a basis for the following stock assessment. No age composition data is available.

4.5.3.1.1. Landing statistics

Landing statistics for Dover sole for 1970-83 are presented in Table 4.5.6. and Fig. 4.5.12. LPUE has been standardized (Stanley and Leaman, 1984) over the time period for 25% qualified landings from Dundas, Two Peaks, and Butterworth according to a log-linear model:

$$\mathrm{Log}_e(\mathrm{LPUE}) = \log_e \mu + \alpha \log_e \mathrm{Hp} + M_i + L_j + \varepsilon$$

where:

μ = mean LPUE

Hp = Horsepower

M_i = month

L_j = locality

ε = error term.

The LPUE time series shows an initial decline after the first significant exploitation in 1970 then a peak in 1973-74 and moderate fluctuations 0.3 (t/h) from 1976-83 (Fig. 4.5.13.).

4.5.3.2. Assessment

The relationship between LPUE and effort was examined using Gulland's (1961) method. Coefficients of determination ranged from 0.10 to 0.40. The highest coefficient of determination was achieved regressing LPUE on a 5-year moving average of effort. The number of years for the moving average should be equivalent to the number of years a cohort contributes significantly to the fishery. The estimated MSY determined from regression coefficients ($a^2/4b$) is 800 t, while the optimum level of effort ($a/2b$) is estimated at 2300 h.

Several considerations must be taken into account in undertaking the above analysis. The technique used is not effective if real changes in abundance are due to recruitment fluctuations. In the case of Dover sole, recruitment is variable, but the number of age classes involved in the fishery, may dampen the effect of variations in recruitment.

Fishing effort must vary from year to year. A constant trend in effort would not meet the equilibrium situation assumed by the regression model. The Dover sole effort data does not exhibit a constant trend over time.

Changes in catch due to changes in availability will cause results from this analysis to be unreliable. It is possible that marketing problems (landing limits imposed by fish companies) for the species could affect the analysis.

4.5.3.1.3. Conclusions

Catch levels in 1983 are 86% of the estimated MSY while current effort levels are 78% of the estimated optimum effort level. This indicates that true MSY may be higher than 800 t. Results of the analysis must be interpreted with caution due to the low coefficient of determination.

4.5.3.4. Yield options

Conservative: 800 t. - equivalent to MSY for the Gulland analysis.

Table 4.5.6. Dover sole, Areas 5C, 5D, 5E, 1970-83.

Year	Landings (t)[a]	Effort (h)[b]	LPUE (kg/h)[c]
1970	965	1471	0.656
1971	903	1672	0.540
1972	922	1893	0.487
1973	768	1171	0.656
1974	767	1166	0.658
1975	882	1873	0.471
1976	1022	2561	0.399
1977	577	2281	0.253
1978	483	1605	0.301
1979	697	3212	0.217
1980	807	2903	0.278
1981	840	2601	0.323
1982	512	1753	0.292
1983	686	1786	0.384

[a] 0% qualified Canadian landings, Areas 5C, D, and E.

[b] Effort = landings (t)/LPUE (t/h).

[c] LPUE = 25% qualified landings--Dundas, Two Peaks, Butterworth. Standardized by log linear model.

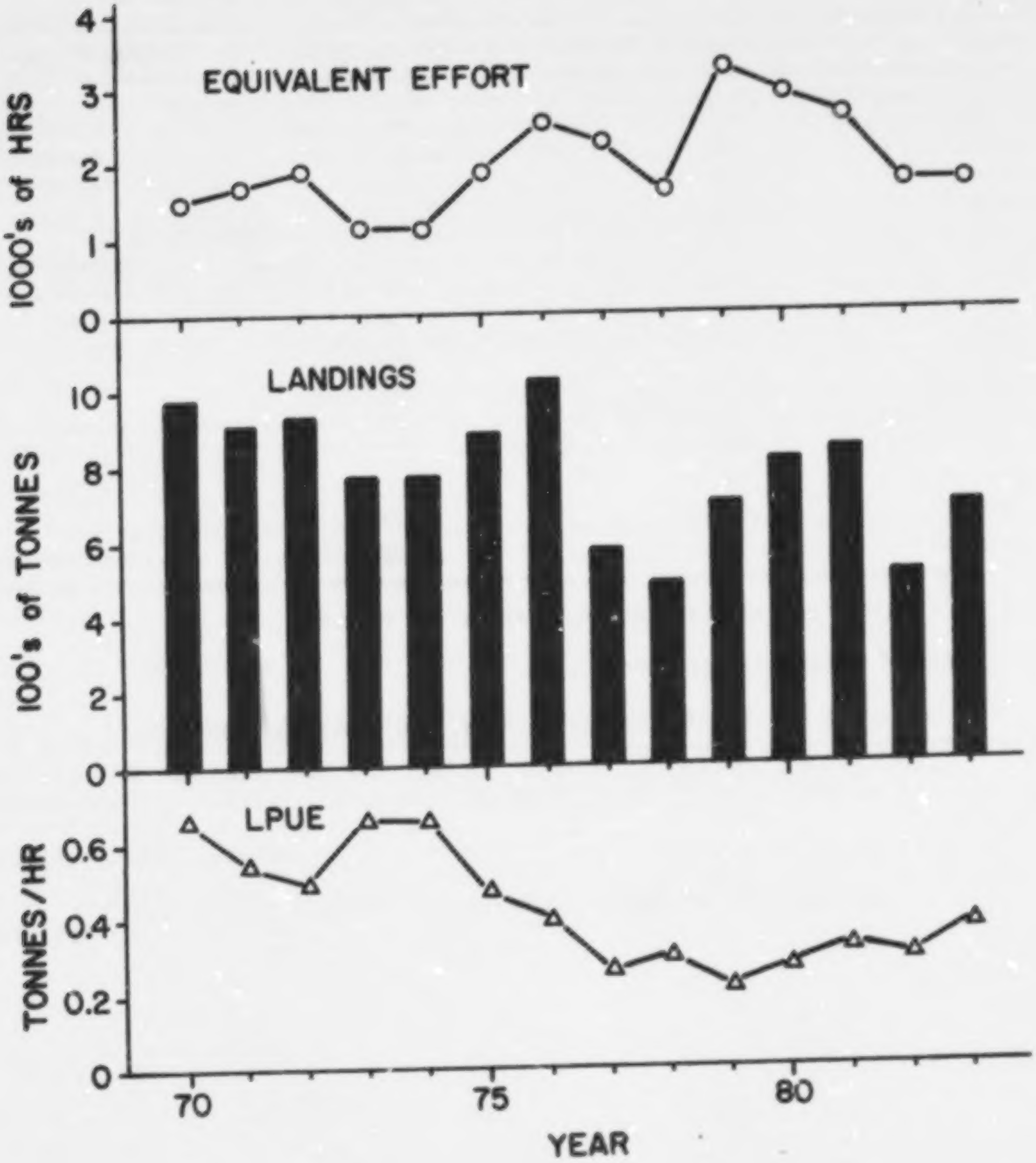

Fig. 4.5.12. Landing statistics for Dover sole from Area 5C, D, and E, January-December 1970-84.

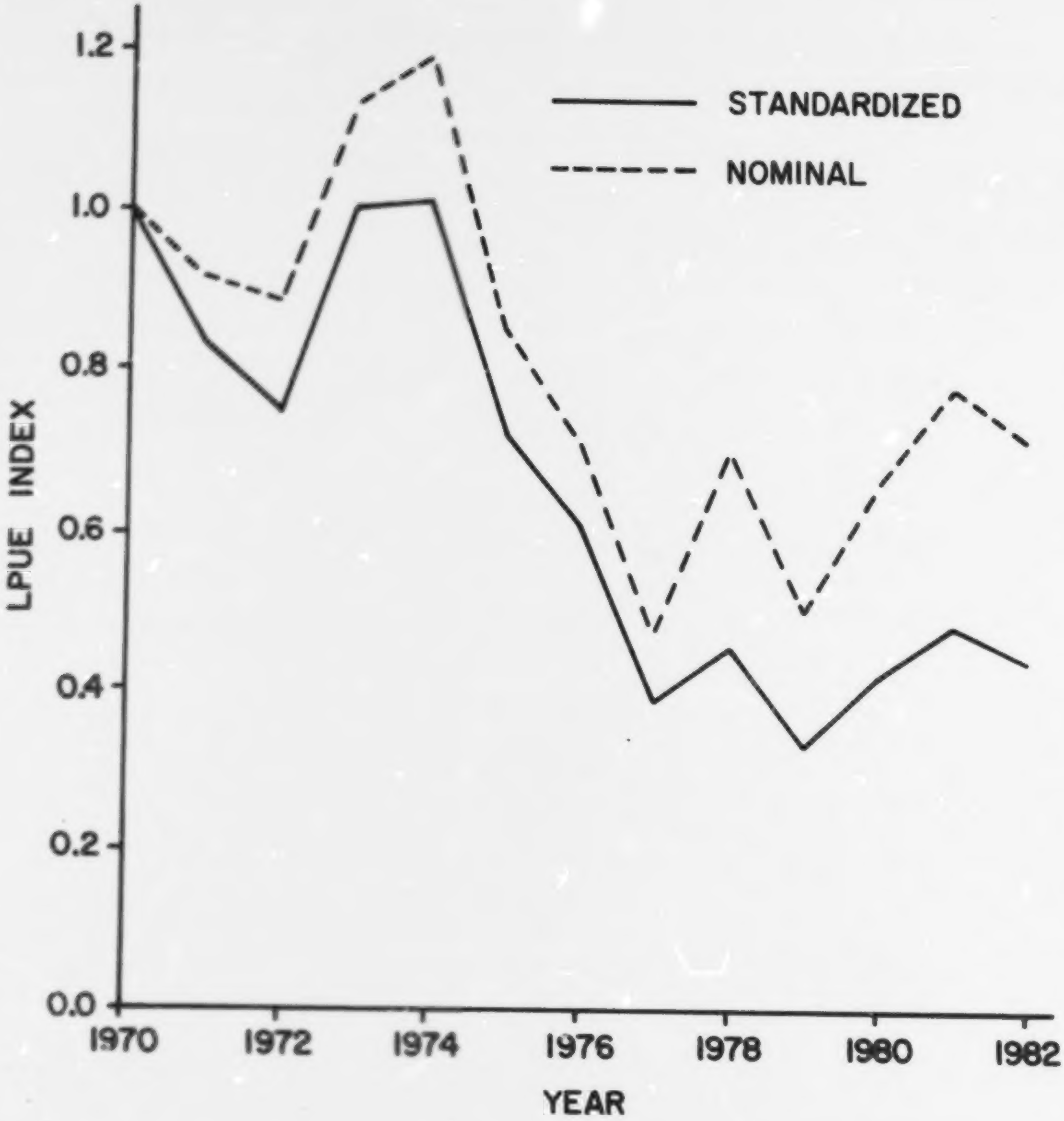

Fig. 4.5.13. LPUE time series (standardized and nominal) for Dover sole from Areas 5C, D, and E, 1970-82. (Source: Stanley and Leaman 1984.)

4.6. West Coast of Queen Charlotte Islands

Yield options are not proposed for flatfish species for this region.

5. Sablefish

by G. A. McFarlane, W. Shaw, and A. V. Tyler

5.1. Coastwide

5.1.1. Introduction

The importance of the domestic sablefish fishery off the west coast of Canada has increased steadily since the extension of Canada's fishery jurisdiction zone in 1977. Initially, a quota of 5,000 t was established for 1977. This was reduced to a more conservative quota of 3,500 t in 1978, based upon analysis of Japanese longline landings and effort data from 1968-1978.

Effective management of sablefish (Anoplopoma fimbria) has been limited by a general lack of biological information. New ageing information has shown that sablefish are much older than previously thought (Beamish and Chilton 1982), with the majority ranging from 4-35 years of age. This represents a substantial decrease in mortality rates and a corresponding increase in the length of time a cohort is available to the fishery. It is also evident that strong year-classes are an important component of the stock and that the fishery is supported by these strong year classes. These biological characteristics must be considered when evaluating exploitation strategies.

5.1.2. The Fishery

An overview of the sablefish fishery off Canada is presented in McFarlane and Beamish (1983). The first commercial fishery occurred late in the nineteenth century, carried out by specially equipped longline vessels. During the first half of this century, landings have fluctuated from a low of 397 t in 1931 to a high of 5,956 t in 1917 (Table 5.1.1). Landings during this period were closely linked to salmon and halibut production.

From 1951-1971 landings by Canadian fishermen in the Canadian zone were fairly stable, averaging about 400 t/year (Tables 5.1.2, 5.1.3). This fishery has traditionally been carried out by longlining and trawling. In 1973, the introduction of traps changed the scope of the fishery. Since 1980, trap-caught sablefish have accounted for 80-90% of the landings. Coastwide landings have remained at approximately 4000 t annually from 1981-1983, a 14% overrun of the quota.

Heavy exploitation of sablefish in foreign nations began in the late 1960s when Japan increased the size of its distant water longline fleet. In 1968, the Japanese fleet began fishing sablefish as a target species, and continued until 1979 (Table 5.1.4). Japan was allocated 200 t in 1980 in exchange for experimental work on a potential B.C. squid fishery. The USSR and the Republic of Korea (R.O.K.) also fished off the west coast of Canada but to a lesser extent than Japan (Table 5.1.4).

In 1981 licence limitation was implemented in an attempt to control effort directed towards sablefish. There are currently 49 sablefish or "K" licences in the fishery, of which 16 are longline and 31 are trap vessels. Two licences have not been identified by gear.

5.1.3. Trends in LPUE

Japan

The Japanese landings show an initial decline from 1968-1971 in LPUE from 0.261 t per 10-hachi to 0.162 t per 10-hachi (Table 5.1.5). LPUE then remained relatively steady from 1972 to 1976, ranging from 0.194 to 0.210 t per 10-hachi. During 1977, LPUE dropped by 24% to 0.147 t per 10-hachi and 1978 LPUE was only slightly higher at 0.162 t per 10-hachi. (If a correction to the 1977 and 1978 landings for the discrepancy in recovery rates is made, the drop in LPUE in 1977 is only 13% to 0.170 t per 10-hachi.)

A similar pattern of change in LPUE is seen in the Queen Charlotte Islands-Dixon Entrance area, Sub-zone 5-5 (Table 5.1.6), where LPUE declined from 1968 to 1971 from 0.289 t per 10-hachi to 0.180 t per 10-hachi. During 1972-75, LPUE was relatively consistent, varying between 0.194 t per 10-hachi and 0.202 t per 10-hachi. A drop in LPUE in 1976 to 0.184 t per 10-hachi precedes the drop in 1977 to 0.140 t per 10-hachi. However, there was an increase in LPUE in 1978 to 0.162 t per 10-hachi.

The pattern of landings and effort in Queen Charlotte Sound, Sub-zone 5-4, and off Vancouver Island, Sub-zones 5-1, 5-2, and 5-3 was different from Sub-zone 5-5 (Tables 5.1.7, 5.1.8). In the former areas, LPUE was almost as high between the years 1972 and 1976 as the initial high LPUEs in 1969 and 1970. However, there were low LPUEs in 1971 and 1977. The increase in LPUE in 1978 from the low of 1977 is less pronounced in these areas than in the Queen Charlotte Islands-Dixon Entrance area.

Within each sub-zone, the blocks with highest landings are included for comparison.

Canada

Accurate landings and effort statistics for the Canadian trap fishery were unavailable until 1977 when a concerted attempt was made to collect this information. The change from Canadian rectangular traps to Korean conical traps around 1978 further complicated the situation in that the change-over was so complete that we have very little information to standardize the two types of traps.

The LPUE data for 1978 are incomplete and probably not representative of the annual landings and LPUE for Korean traps. The coast-wide LPUE from 1979 to 1983 is similar and has varied from 14.8 to 17.1 kg/trap (Table 5.1.9; Fig. 5.1.1). There has been considerable variation between and within Areas (Table 5.1.10). The first quarter (January to April) landing statistics have been included for comparison (Table 5.1.10; Fig. 5.1.2) showing the substantial increases in landings made in this quarter from 1979 to 1982. Reduced landings in the first quarter of 1983 are due to a self-imposed industry closure. Off Vancouver Island, both landings and LPUE declined by [illegible] and 30% in 1981 and 1982 respectively, from 1980 levels (Table 5.1.10; Fig. 5.1.2). Landings remained lower than the previous 2 years in 1983, however LPUE increased to 13.7 kg/trap.

In Queen Charlotte Sound (Table 5.1.10; Fig. 5.1.2) landings increased substantially in 1981 from previous levels, and have remained stable since. LPUE in this area has remained relatively constant, ranging from 14.0 to 18.5 kg/trap from 1979 to 1983. Off the west coast of the Queen Charlotte Islands (Table 5.1.10; Fig. 5.1.2) landings have increased steadily since 1980. Effort decreased between 1980 and 1982 and returned to the 1980 levels in 1983.

5.1.4. Stock assessment

For previous stock assessments, Canadian scientists used two methods to estimate MSY (Westrheim 1980). The first method involves a regression of LPUE on the average fishing effort over a number of preceding years (K), which ideally should be equal to the average length of time an individual of a year class is vulnerable to the fishery (Gulland 1961); the second is a dynamic, stochastic version of the Schaefer model (Schnute 1977). Using Gulland's (1961) linear regression model, estimates of MSY using landings-per-10-hachi and landings-per-boat-day ranged between 3,200 and 4,100 t/yr. Results generated by the modified Schaefer model produced estimates ranging from 5,200 to 6,200 t/yr.

Because some of the assumptions of the surplus production model have not been met, alternative models have now been applied.

A minimum number of years of age composition data has now been accumulated to allow age-structured models to be used to assess the stock. Our analysis suggests that the stock will experience a rapid increase in biomass over the next few years due to the entry of the large 1977 year-class and the slightly above-average 1978, and possibly 1979, year-classes. Yield per recruit calculations over a range of fishing mortality are presented in Table 5.1.11. A natural mortality estimate of $M = 0.1$ was used in all calculations. Y/R is maximized at $F_{max} = 1.212$ and $F_{0.1} = 0.205$.

A forward simulation model (Tyler 1980) was used to project sablefish biomass and yield from 1977 to 2020. Numbers at age and total biomass (cohort analysis, Pope 1972) for 1977 to 1982 are presented in Table 5.1.12. The cohort analysis included 6 years of age composition data with accumulated F values of 0.4 or less. Therefore, the estimates of stock size may be off by a factor of 2 (Pope 1972, Fig. 1). The model was run at 2 recruitment levels; 1.41×10^6, and 2.54×10^6 age-4 fish. The first level is the average recruitment of age-4 fish for a series of poor year-classes (1971-75) and the second level is the average recruitment of year-classes prior to 1970 representing reasonably strong recruitment years. In addition we carried out a forward simulation on the exceptionally strong 1977 year class in order to see when cohort biomass was maximized (Table 5.1.13; Fig. 5.1.3). Biomass, population numbers and yield projected to 2020 are presented in Tables 5.1.14 and 5.1.15, and Figure 5.1.4, 5.1.5, respectively. The 1977 year-class maximizes in the total stock in 1984 and in the recruited stock in 1987 (Table 5.1.14; Fig. 5.1.3). These results indicate that yield may be increased over the next few years to capitalize on this year-class. Both the low and high average recruitment runs project a landings in 1985 of approximately 5000 t (4928 and 5406 t respectively), declining thereafter (Tables 5.1.14; 5.1.15).

Table 5.1.1. Sablefish landings in the Canadian zone, 1913-1950 (round weight, tonnes).[a]

Year	Vancouver Island[b]	Queen Charlotte Sound and Queen Charlotte Islands[c]	Total
1913			1988
1914			3209
1915			2441
1916			4312
1917			5956
1918	1013	1026	2039
1919	446	270	716
1920	743	1011	1754
1921	774	609	1383
1922	843	450	1293
1923	727	408	1135
1924	786	452	1238
1925	406	611	1017
1926	343	362	705
1927	578	540	1118
1928	610	301	911
1929	729	313	1042
1930	746	378	1124
1931	337	60	397
1932	280	156	436
1933	208	205	413
1934	206	229	435
1935	348	311	659
1936	208	282	490
1937	396	516	912
1938	342	234	576
1939	403	214	617
1940	319	629	948
1941	348	840	1188
1942	277	558	835
1943	591	835	1426
1944	844	675	1519
1945	734	694	1428
1946	411	1208	1619
1947	346	559	891
1948	364	1119	1483
1949	691	1204	1895
1950	290	358	648

[a] Fishery Statistics of Canada. Converted from dressed weight to round weight by a factor of 1.5.

[b] Listed as District 1 or South Coast and District 3 or Fraser.

[c] Listed as District 2 or North Coast.

Table 5.1.2. Canadian sablefish landings, by gear, from the west coast of Vancouver Island, 1951-1983 (round wt, metric tons).[a]

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%	Wt	%	Wt	%	Wt	%	Total
1951	196.1	89.8	21.8	9.9			0.5	0.2	218.4
1952	115.1	78.3	31.3	21.3			0.6	0.4	147.0
1953	129.4	94.6	6.3	4.6			1.1	0.8	136.8
1954	103.7	80.8	24.3	18.9	0.3	0.2			128.3
1955	115.5	89.3	13.9	10.7					129.4
1956	48.3	60.8	31.1	39.2					79.4
1957	123.6	74.8	41.2	25.0	0.3	0.2			165.1
1958	78.6	41.2	111.4	58.4	0.6	0.3			190.6
1959	143.8	72.5	54.6	27.5					198.4
1960	208.9	80.9	49.2	19.1					258.1
1961	198.1	69.4	87.4	30.6					285.5
1962	152.5	64.4	83.2	35.1			1.1	0.5	236.8
1963	64.5	76.0	20.4	24.0					84.9
1964	108.4	71.6	42.9	28.4					151.3
1965	54.0	44.1	68.5	55.9					122.5
1966	127.2	55.9	100.3	44.1					227.5
1967	55.7	34.4	106.3	65.6					162.0
1968	68.4	35.9	122.3	64.1					190.7
1969	18.2	12.5	126.8	87.3			0.3	0.2	145.3
1970	12.0	14.8	69.3	85.2					81.3
1971	14.6	8.1	166.7	91.9					181.3
1972	100.3[c]	13.7	632.7	86.3					733.0
1973	3.2	0.8	50.9	12.5	353.4	86.7	Tr		407.5
1974	2.3	0.9	83.7	33.6	161.5	64.8	1.8	0.7	249.3
1975	2.3	0.9	200.3	81.8	41.5	16.9	0.9	0.4	245.0
1976	41.7	13.3	224.8	71.5	47.6	15.1	0.1	0.1	314.2
1977	27.3	3.5	688.4	87.1	68.9	8.7	5.9	0.7	790.5
1978	18.2	5.1	89.9	25.4	239.5	67.7	6.4	1.8	354.0
1979	118.3	17.5	143.4	21.2	409.8	60.5	6.0	0.9	677.5
1980	69.1	3.6	106.8	5.6	1722.5	90.6	3.0	0.2	1901.4
1981	94.8	8.6	140.2	12.8	862.4	78.6			1097.4
1982	161.9	13.2	153.2	12.5	913.3	74.2	1.9	0.2[d]	1230.3
1983	343.1	27.1	146.7	11.6	777.0	61.3			1266.8

[a] Canada Department Fisheries, B.C. Catch Statistics, 1951-1971 (converted from dressed weight to round weight by a factor of 1.5). Fisheries Research Board Canada Catch and Effort Statistics of the Canadian Groundfish Fishery of the Pacific Coast, 1972-1981.

[b] Includes troll and handline.

[c] Includes longline, handline, and others.

[d] Incidental to halibut longline.

Table 5.1.3. Canadian sablefish landings, by gear, from Queen Charlotte Sound and the west coast of Queen Charlotte Islands, 1951-1983 (round wt, metric tons).[a]

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%	Wt	%	Wt	%	Wt	%	Total
1951	576.7	99.8	1.3	0.2					578.0
1952	338.1	99.2	2.7	0.8					340.8
1953	206.2	99.2	1.7	0.8					207.9
1954	328.6	99.4	2.1	0.6					330.7
1955	243.5	99.8	0.6	0.2					244.1
1956	124.5	95.4	6.0	4.6					130.5
1957	342.0	98.3	5.9	1.7					347.9
1958	88.5	93.5	6.2	6.5					94.7
1959	154.5	98.3	2.7	1.7					157.2
1960	214.4	93.2	15.7	6.8					230.1
1961	123.2	92.1	10.6	7.9					133.8
1962	125.2	80.4	30.5	19.6					155.7
1963	157.8	77.9	44.5	22.0			0.2	0.1	202.5
1964	166.1	66.9	82.2	33.1			0.1	-	248.4
1965	139.2	41.8	193.4	58.1			0.3	0.1	332.9
1966	198.5	48.6	209.4	51.3			0.2	0.1	408.1
1967	197.2	85.8	32.6	14.2			0.1	0.1	229.9
1968	223.9	82.1	33.7	12.4			15.1	5.5	272.7
1969	144.1	86.9	21.4	12.9			0.3	0.2	165.8
1970	130.1	73.2	47.2	26.5			0.5	0.3	177.8
1971	108.4	82.7	22.7	17.3					131.1
1972	299.4	84.3	55.8	15.7					355.2
1973	116.6	21.6	31.7	5.9	392.4	72.6			540.7
1974	39.0	16.1	38.1	15.7	165.6	68.2			242.7
1975	149.9	22.7	82.0	12.4	427.9	64.9			659.8
1976	47.7	10.4	154.2	33.7	255.8	55.9			457.7
1977	49.8	16.9	98.3	33.4	145.7	49.4	0.9	0.3	294.7
1978	39.0	8.2	40.4	8.5	395.1	83.0	1.4	0.3	475.9
1979	158.7	11.7	133.1	9.8	1067.6	78.5			1359.4
1980	179.7	9.5	226.7	12.0	1488.3	78.6			1894.7
1981	284.8	10.2	92.9	3.3	2412.6	86.5			2790.3
1982	110.0	4.0	94.6	3.4	2524.5	91.9	16.5	0.6[c]	2745.8
1983	109.4	3.5	127.0	4.0	2797.5	92.0	15.6	0.1[d]	3147.0

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[a] Canada Department Fisheries B.C. Catch Statistics, 1951-1971 (converted from dressed weight to round weight by a factor of 1.5). Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1972-1981.

[b] Includes troll, handline, and sunken gillnet (1968 only).

[c] Incidental to halibut longline.

[d] Includes troll, handline, sunken gillnet and catch incidental to halibut longline fishery.

However, there is a great deal of uncertainty in some of the estimates used in the yield per recruit analysis, cohort analysis, and in the forward simulations. We chose the conservative $F_{0.1}$ level to calculate potential yield because of the high uncertainty involved in the estimates from cohort analysis. It is unknown if it is conservative for a long-lived species with irregular recruitment such as sablefish. The biomass estimates must be considered tentative since only 6 years of age composition data were available for use in cohort analysis. In addition, the importance of longevity in the dynamics of a population is poorly understood (Leaman and Beamish 1984). Sablefish are long-lived and most commercial landings contain 25-30 age groups. Our analysis does not consider the consequences of changes in age composition.

5.1.5 Recommendations

It is recommended that the yield option for sablefish be increased in a "stepwise" fashion over the next few years in order to take advantage of the increase in exploitable biomass. Because of the above-mentioned concerns, a conservative approach to increasing recommended yield is proposed. Continued close monitoring of the fishery is essential in order to assess this strategy.

The recommended yield option at the conservative level for 1985 is 4,000 t. It is anticipated that the recommended yield will remain at 4,000 t through 1986, at which time more recent age composition data will be available for further age-structured analysis. An alternative suggested yield option at a high risk level could be as much as 5000 t in 1985. There is a possibility that this risk level option will interfere with future yield for the fishery.

Table 5.1.4. Sablefish landings by nation (all fishing gears) in British Columbia waters, 1964-1983.

Calendar Year	Canada[a]	USA[b]	Japan[c]	USSR	R.O.K.[d]	Total
1964	399	83				482
1965	456	92				548
1966	636	95	174			905
1967	392	65	1189			1646
1968	464	65	2390			2919
1969	311	43	4720			5074
1970	259	104	5142			5505
1971	312	161	3050			3523
1972	1088	582	4236			5906
1973	949	82	2950	6		3981
1974	492	227	3866	65	129	4779
1975	905	541	4702		1263	7411
1976	772	473	3494		2335	7074
1977	1086	571	2961		168[e]	4804
1978	830	948	2103			3881
1979	2037	1236	1112[d]			4385
1980	3796	407	199			4402
1981	3887					3887
1982	3976					3976
1983	4414					4414

[a] Canada Department of Fisheries, B.C. Catch Statistics, 1965-1971, and Fisheries Research Board of Canada Catch and Effort Statistics of the Canadian Groundfish Fishery of the Pacific coast (1972-1983).

[b] Ketchen (1977) until 1973, from INPFC Statistical Yearbooks, 1974-1979 (1979 preliminary) and from PMFC data series 1980.

[c] INPFC Statistical Yearbooks, 1964-1978, and from fishing log books for 1979-1980.

[d] Best estimate of catch using fishing log books plus observer information. These figures differ from previously published estimates (Ketchen 1980a) as a result of a change in conversion rates.

[e] Ketchen (1977).

Table 5.1.5. Sablefish landings (t) and effort (10-hachi) statistics for Japanese longline fishery in Canadian waters (48°00'-54°30'N lat.), 1968-1978.

Calendar year	Landings (t)	Effort (10-hachi)	LPUE (t/10-hachi)
1968[a]	1454	5573	0.261
1969	4224	22412	0.207
1970	4919	22886	0.215
1971	2721	16774	0.162
1972	3491	16831	0.207
1973	2585	12367	0.209
1974	3527	16765	0.210
1975	4433	22807	0.194
1976	3209	16519	0.194
1977[b]	2982(3440)[c]	20260	0.147(0.170)[c]
1978	2091(2405)[c]	13396	0.162(0.180)[c]
1968-78 average	3240	16781	0.197

[a] 1968-1976 statistics from U.S. National Marine Fisheries Service computer printouts.

[b] 1977 and 1978 statistics from fishing log books.

[c] Landings and LPUE corrected for change in recovery rates reported by observers on board vessels.

Table 5.1.6. Sablefish landings (t) and effort (10-hachi) statistics for Japanese longline fishery in the Queen Charlotte Islands-Dixon Entrance area, Sub-zone 5-5 (52°00'-54°30'N lat.), 1968-1978.

	Total for Sub-zone 5-5			Block with the largest landings (033540)[f]		
Year[a]	Landings (t)	Effort (10-hachi)	LPUE (t/10-hachi)	Landings (t)	Effort (10-hachi)	LPUE (t/10-hachi)
1968[b]	1142	3954	0.289	478	1532	0.312
1969	1490	6650	0.224	580	2128	0.273
1970	1549	7229	0.214	708	2971	0.238
1971	1472	8164	0.180	786	4484	0.175
1972	2080	10284	0.202	1221	5996	0.204
1973	1327	6589	0.201	752	3731	0.202
1974	1151	5875	0.196	694	3559	0.195
1975	1610	8284	0.194	935	4759	0.196
1976	1259	6850	0.184	717	4098	0.175
1977[c]	737	5246	0.140	377	2743	0.138
1978	555	3424[d]	0.162	219[e]	1363[e]	0.161

[a] Calendar year.

[b] 1968-1976 data from U.S. National Marine Fisheries Services computer printouts.

[c] 1977 and 1978 data from Japanese log books.

[d] One log book unavailable, therefore, effort estimated.

[e] Landing and effort in this block probably higher -- missing information from one log book.

[f] Japanese fishing area contained within Japanese sub-zone 5.5 (within PMFC area 5E; Fig. 1.1).

Table 5.1.7. Sablefish landings (t) and effort (10-hachi) statistics for Japanese longline fishery adjacent to Queen Charlotte Sound, Sub-zone 5-4 (50°30'-52°00'N lat.), 1968-1978.

	Total for Sub-zone 5-4			Block with the largest landings					
				Landings (t)					
Year[a]	Landings (t)	Effort (10-hachi)	LPUE (t/10-hachi)	029510	029503	030510	030513[d]	Effort (10-hachi)	LPUE (t/10-hachi)
1968[b]	73	466	0.157	22	-	-	-	189	0.116
1969	765	3700	0.207	-	-	246	-	1051	0.234
1970	2310	10756	0.215	-	-	886	-	3988	0.222
1971	665	4458	0.147	-	-	-	338	1843	0.183
1972	586	2503	0.234	-	-	-	295	1140	0.259
1973	460	2156	0.213	-	178	-	-	872	0.204
1974	820	3756	0.218	-	-	-	268	1172	0.229
1975	1444	7397	0.195	-	-	-	405	2051	0.197
1976	1126	5327	0.211	-	-	-	741	3382	0.219
1977[c]	1081	7342	0.147	-	-	-	423	2761	0.153
1978	765	4924	0.155	-	-	-	304	1954	0.156

[a] Calendar year.

[b] 1968-1976 data from U.S. National Marine Fisheries Services computer printouts.

[c] 1977 and 1978 data from Japanese log books.

[d] Japanese fishing areas contained within Japanese sub-zone 5-4 (within PMFC area 5A-5B; Fig. 1.1).

Table 5.1.8. Sablefish landings (t) and effort (10-hachi) statistics for Japanese longline fishery in the Vancouver Island Area, Sub-zones 5-1, 5-2 and 5-3 (48°00'-50°30'N. lat.), 1968-1978.

	Total for Sub-zones 5-1,2,3			Block with the largest landings						
				Landings (t)						
Year[a]	Landings (t)	Effort (10-hachi)	LPUE	028600	027493	027490	026483	025480[f]	Effort (10-hachi)	LPUE
1968[b]	239	1153	0.207	-	102	-	-	-	466	0.219
1969	1969	10062	0.196	-	796	-	-	-	4367	0.182
1970	1060	4901	0.216	455	-	-	-	-	1858	0.245
1971	594	4152	0.143	-	-	-	200	-	1264	0.158
1972	826	4044	0.204	-	191	-	-	-	826	0.231
1973	798	3622	0.220	-	-	-	211	-	943	0.224
1974	1556	7135	0.218	-	-	-	-	411	1893	0.217
1975	1379	7126	0.194	-	-	371	-	-	1903	0.195
1976	824	4342	0.190	267	-	-	-	-	1295	0.206
1977[c]	1164	7672	0.152	-	-	-	308	-	1942	0.158
1978	771	5048[d]	0.162	-	238[e]	-	-	-	1445[e]	0.165

[a] Calendar year.

[b] 1968-1976 data from U.S. National Marine Fisheries Services computer printouts.

[c] 1977 and 1978 data from Japanese log books.

[d] One log book unavailable, therefore, effort estimated.

[e] Landings and effort in this block probably higher—missing information from one log book.

[f] Japanese fishing areas contained within Japanese sub-zone 5-1,2,3 (with PMFC areas 3C-3D; Fig. 1.1).

Table 5.1.9. Summary of sablefish total trap landings and LPUE estimate for January 1-April 30 and for all months combined in B.C. waters from 1977-1983.

	Landing statistics			
	January 1-April 30		January 1-December 31	
Year	Total landings (t)	LPUE (kg/trap)	Total landings (t)	LPUE (kg/trap)
1977	-	-	214.6	-
1978	-	-	634.6	18.9
1979	181.7	18.3	1493.1	17.1
1980	502.1	12.4	3213.8	15.4
1981	781.3	18.8	3275.1	14.8
1982	1176.8	18.1	3342.6	16.5
1983	152.7	15.5	3672.0	16.4

Table 5.1.10. Sablefish total trap landings and LPUE estimates for January 1-April 30 and for all months combined for the three major fishing areas during 1972-1983.

	Vancouver Island				Queen Charlotte Sound				Queen Charlotte Islands			
	1st Qtr.		All Qtrs.		1st Qtr.		All Qtrs.		1st Qtr.		All Qtrs.	
Year	T.L.[a] (t)	LPUE (kg/trap)	T.L. (t)	LPUE (kg/trap)	T.L. (t)	LPUE (kg/trap)	T.L. (t)	LPUE (kg/trap)	T.L. (t)	LPUE (kg/trap)	T.L. (t)	LPUE (kg/trap)
1977	-	-	53.6	-	-	-	17.3	-	-	-	128.6	-
1978	-	-	141.3	25.2	-	-	77.6	11.6	-	-	326.4	20.1
1979	15.1	-	392.0	14.1	-	-	281.3	14.0	163.4	18.3	759.7	20.9
1980	275.7	16.9	1714.1	15.0	31.3	8.6	797.2	18.5	193.1	9.9	682.8	13.5
1981	240.1	12.5	860.6	10.3	198.7	22.4	1359.1	17.9	342.3	24.2	991.8	18.5
1982	222.0	12.6	913.3	11.8	369.1	16.8	1519.2	16.6	586.8	30.9	985.7	24.8
1983	87.7	16.3	770.0	13.7	18.7	11.6	1587.0	17.0	35.0	14.9	1285.2	17.9

[a] T.L. = Total landings.

Table 5.1.11. Yield-per-recruit calculations for sablefish at M = 0.1.

	Fishing mortality	Landings (number)	Yield (kg)	Average weight (kg)
	0.100	0.26765	1.206	4.504
	0.200	0.37666	1.577	4.188
$F_{0\cdot 1}$	0.205	0.38080	1.590	4.174
	0.300	0.44146	1.745	3.953
	0.400	0.48734	1.837	3.770
	0.500	0.52283	1.893	3.622
	0.600	0.55174	1.929	3.497
	0.700	0.57610	1.953	3.390
	0.800	0.59711	1.968	3.296
	0.900	0.61555	1.978	3.214
	1.000	0.63195	1.984	3.140
	1.100	0.64669	1.987	3.073
	1.200	0.66005	1.988	3.012
F_{max}	1.212	0.66157	1.988	3.006
	1.300	0.67226	1.988	2.957
	1.400	0.68346	1.986	2.906
	1.500	0.69381	1.983	2.859
	1.600	0.70340	1.980	2.815
	1.700	0.71233	1.976	2.774
	1.800	0.72068	1.972	2.736
	1.900	0.72850	1.967	2.700
	2.000	0.73584	1.962	2.667

[a] M=mortality

Table 5.1.12. Cohort analysis (M = 0.1) based upon catch-at-age from 1977-1982.

	Population numbers (x 10^3)					
Age	1977	1978	1979	1980	1981	1982
4	716	681	708	2479	8231	2465
5	684	647	575	630	2131	7142
6	616	615	583	497	525	1844
7	606	540	508	501	416	430
8	589	536	453	427	415	333
9	706	514	391	374	347	357
10	633	619	427	311	293	283
11	623	555	458	318	223	235
12	564	531	443	356	209	166
13	568	447	415	329	237	141
14	575	461	343	302	219	171
15	580	449	379	223	202	156
16	628	475	330	267	124	122
17	402	451	357	216	174	75
18	435	327	390	226	121	122
19	424	300	278	280	148	75
20	387	305	254	171	201	110
21	270	266	248	157	107	150
22	283	186	212	150	94	64
23	245	199	131	145	101	58
24	193	147	152	63	101	64
25	122	141	100	89	35	75
26	151	107	113	57	63	17
27	122	90	83	66	30	41
28	128	89	74	53	45	17
29	73	101	66	44	30	29
30	70	65	84	52	27	17
31	77	47	48	55	24	17
32	30	42	38	32	40	17
33	34	15	33	28	24	29
34	19	23	12	23	21	17
35	89	13	16	9	15	17
Total no.	11641	9984	8704	8930	14974	14857
Total biomass	49859	42435	39919	40185	45864	49629

Table 5.1.13. Results of projected biomass and population numbers of the 1977 sablefish cohort from 1982-2020. Age 4 recruits were 8.23 x 10^6 fish and fishing mortality was F = 0.0. BIOM = Biomass of 1977 cohort; RBIOM = Recruited biomass of 1977 cohort; FPOP = number of fish in 1977 cohort; RFOPO = Number of recruited fish in 1977 cohort.

Time	BIOM (t)	RBIOM (t)	FPOP (x 10^6)	RFPOP(x 10^6)
1982	18321.0	0.0	7.4477	0.0
1983	19206.0	9603.0	6.7390	3.3695
1984	19513.0	13659.0	6.0977	4.2684
1985	19311.0	15449.0	5.5174	4.4139
1986	18821.0	16939.0	4.9924	4.4931
1987	18114.0	18114.0	4.5173	4.5173
1988	17208.0	17208.0	4.0874	4.0874
1989	16199.0	16199.0	3.6984	3.6984
1990	15160.0	15160.0	3.3465	3.3465
1991	14111.0	14111.0	3.0280	3.0280
1992	13069.0	13069.0	2.7399	2.7399
1993	12073.0	12073.0	2.4791	2.4791
1994	11104.0	11104.0	2.2432	2.2432
1995	10189.0	10189.0	2.0297	2.2097
1996	9329.8	9329.8	1.8366	1.8366
1997	8525.1	8525.1	1.6618	1.6618
1998	7789.0	7789.0	1.5037	1.5037
1999	7088.6	7088.6	1.3606	1.3606
2000	6463.3	6463.3	1.2311	1.2311
2001	5881.6	5881.6	1.1139	1.1139
2002	5342.1	5342.1	1.0079	1.0079
2003	4852.0	4852.0	0.91202	0.91202
2004	4406.7	4406.7	0.82523	0.82523
2005	3994.8	3994.8	0.74670	0.74670
2006	3628.2	3628.2	0.67564	0.67564
2007	3289.0	3289.0	0.61135	0.61135
208	2981.6	2981.6	0.55317	0.55317
2009	2702.8	2702.8	0.50053	0.50053
2010	2445.6	2445.6	0.45290	0.45290
2011	2217.0	2217.0	0.40980	0.40980
2012	2006.0	2006.0	0.37080	0.37080

Table 5.1.14. Results of projected biomass, population numbers and yield assuming an initial 1977 biomass at 49,859 t and an age 4 recruitment of 1.4 x 10^6 fish. Fishing mortality mos F = 0.2. BIOM = biomass of total stock; RBIOM = recruited biomass of total stock; FPOP = number of fish in total stock; RFPOP = number of adult fish recruited in total stock; YIELD = catch of fish from total stock.

Time	BIOM (t)	RBIOM (t)	FPOP ($\times 10^6$)	RFPOP ($\times 10^6$)	Yield (t)
1977	49859				
1978	39031	34601	9.3673	7.6130	8024.0
1979	31849	27855	7.7246	6.1198	6494.7
1980	29459	22448	8.0578	4.9334	5337.6
1981	38722	18268	13.525	4.0353	4953.1
1982	38324	16511	12.947	3.8768	5456.0
1983	36025	20757	11.553	5.6510	5239.0
1984	33275	21770	10.283	5.9343	5355.1
1985	30672	20985	9.2762	5.5771	4928.4
1986	28438	20066	8.5059	5.2076	4482.5
1987	26481	18986	7.8998	4.8395	4176.4
1988	24600	17216	7.3778	4.3471	4125.6
1989	23055	15672	6.9791	3.9484	3823.4
1990	21851	14467	6.6840	3.6533	3542.3
1991	20921	13537	6.4662	3.4355	3325.5
1992	20212	12828	6.3060	3.2753	3160.1
1993	19669	12286	6.1872	3.1565	3033.6
1994	19259	11875	6.0997	3.0690	2937.9
1995	18951	11567	6.0356	3.0049	2866.1
1996	18722	11339	5.9887	2.9580	2812.7
1997	18549	11165	5.9537	2.9230	2772.2
1998	18321	11038	5.9283	2.8976	2742.5
1999	18327	10943	5.9098	2.8791	2720.5
2000	18258	10874	5.8962	2.8655	2704.4
2001	18207	10823	5.8864	2.8557	2692.5
2002	18169	10785	5.8791	2.8484	2683.7
2003	18142	10758	5.8739	2.8432	2677.3
2004	18121	10737	5.8700	2.8393	2672.5
2005	18106	10723	5.8762	2.8365	2669.1
2006	18096	10712	5.8652	2.8345	2666.6
2007	18088	10704	5.8637	2.8330	2664.7
2008	18082	10698	5.8626	2.8319	2663.4
2009	18078	10694	5.8618	2.8311	2662.4
2010	18075	10691	5.8612	2.8305	2661.6
2011	18072	10688	5.8608	2.8301	2661.1
2012	18070	10686	5.8603	2.8296	2660.5
2013	18065	10681	5.8594	2.8287	2659.4
2014	18064	10680	5.8593	2.8286	2659.2
2015	18064	10680	5.8593	2.8286	2659.2
2016	18064	10680	5.8593	2.8286	2659.2
2017	18064	10680	5.8593	2.8286	2659.2
2018	18064	10680	5.8593	2.8268	2659.2
2019	18064	10680	5.8593	2.8286	2659.2
2020	18064	10680	5.8593	2.8286	2659.2

Table 5.1.15. Results of projected biomass, population numbers and yield assuming an initial 1977 biomass at 49,859 t and an age 4 recruitment of 2.54 x 10^6 fish. Fishing mortality was F = 0.2. BIOM = biomass of 1977 cohort; RBIOM = recruited biomass of 1977 cohort; FPOP = number of fish in 1977 cohort; RFPOP = number of recruited in 1977 cohort.

Time	BIOM (t)	RBIOM (t)	FPOP ($x10^6$)	RFPOP ($x10^6$)	Yield
1977	49859				
1978	39031	34601	9.3673	7.6130	8024.0
1979	31849	27855	7.7246	6.1198	6494.7
1980	29459	22448	8.0578	4.9334	5337.6
1981	38722	18268	13.525	4.0353	4953.1
1982	38324	16511	12.947	3.8768	5456.0
1983	38055	20757	12.553	5.6510	5282.1
1984	37321	21770	12.103	5.9343	5621.4
1985	36629	21940	11.766	5.9124	5406.2
1986	36066	22191	11.518	5.9085	5245.1
1987	35533	22250	11.319	5.8658	5181.6
1988	34837	21556	11.114	5.6585	5334.3
1989	34291	21000	10.962	5.5065	5200.7
1990	33856	20565	10.849	5.3942	5099.1
1991	33519	20228	10.767	5.3117	5020.6
1992	33264	19973	10.707	5.2519	4961.2
1993	33068	19777	10.663	5.2074	4915.5
1994	32920	19629	10.630	5.1750	4881.0
1995	32811	19520	10.607	5.1516	4855.5
1996	32732	19441	10.590	5.1349	4837.0
1997	32671	19380	10.578	5.1223	4822.7
1998	32627	19337	10.569	5.1135	4812.7
1999	32596	19305	10.563	5.1072	4805.4
2000	32574	19283	10.558	5.1028	4800.2
2001	32558	19267	10.555	5.0997	4796.5
2002	32547	19256	10.553	5.0974	4793.9
2003	32539	19248	10.551	5.0959	4792.0
2004	32533	19242	10.550	5.0947	4790.6
2005	32529	19238	10.549	5.0940	4789.7
2006	32526	19235	10.549	5.0934	4789.0
2007	32524	19233	10.548	5.0931	4788.6
2008	32523	19232	10.548	5.0928	4788.3
2009	32522	19231	10.548	5.0926	4788.0
2010	32521	19230	10.548	5.0925	4787.9
2100	32521	19230	10.548	5.0924	4787.7
2012	32510	10229	10.547	5.0922	4787.5
2013	32516	19225	10.547	5.0915	4786.6
2014	32516	1925	10.547	5.0915	4786.6
2015	32516	19225	10.547	5.0915	4786.6
2016	32516	19225	10.547	5.0915	4786.6
2017	32516	19225	10.547	5.0915	4786.6
2018	32516	19225	10.547	5.0915	4786.6
2019	32516	19225	10.547	5.0915	4786.6
2020	32516	19225	10.547	5.0915	4786.6

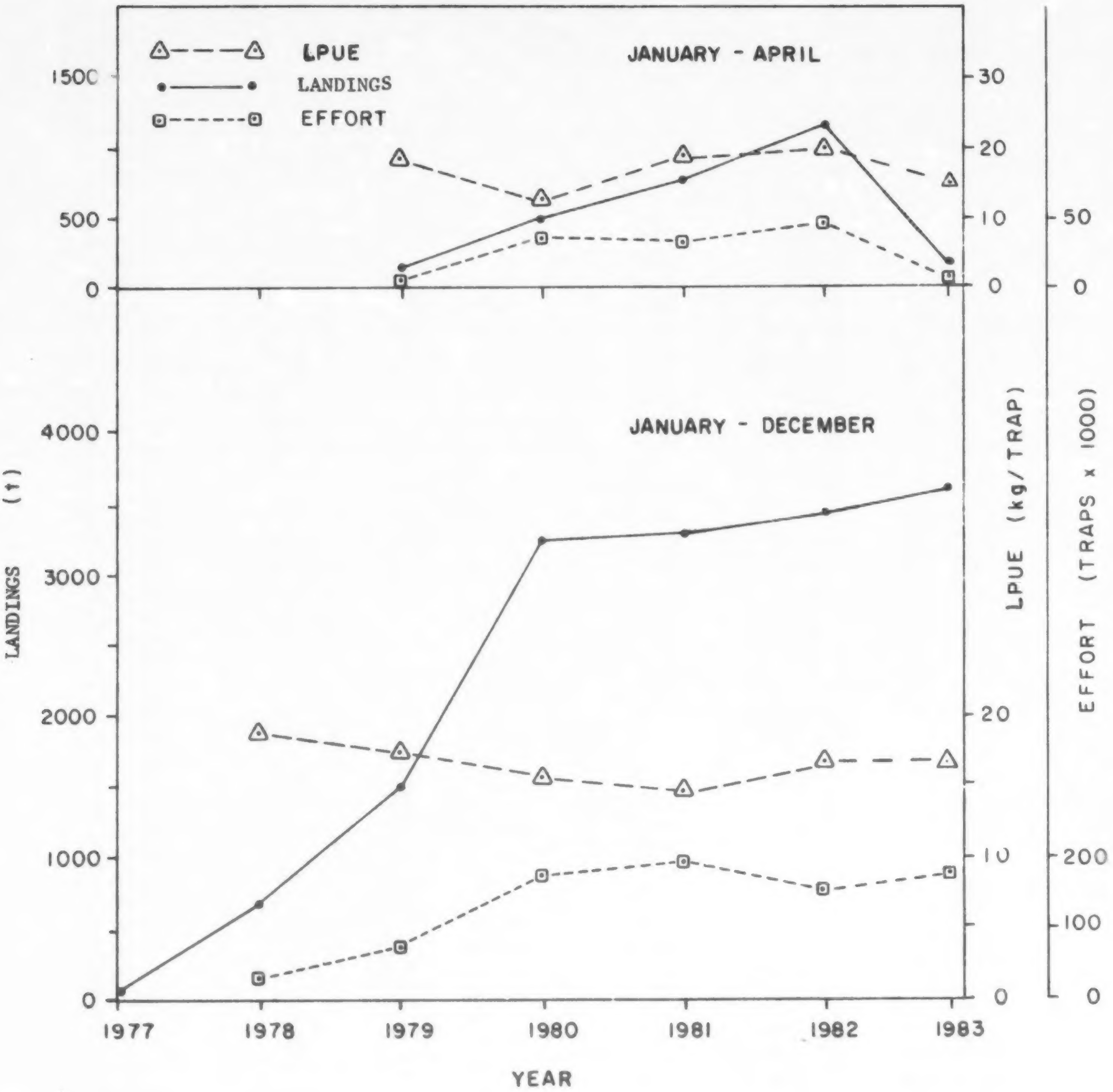

Fig. 5.1.1. Trends in landings and LPUE for the Canadian trap fishery for sablefish in Canadian waters, 1977-1983.

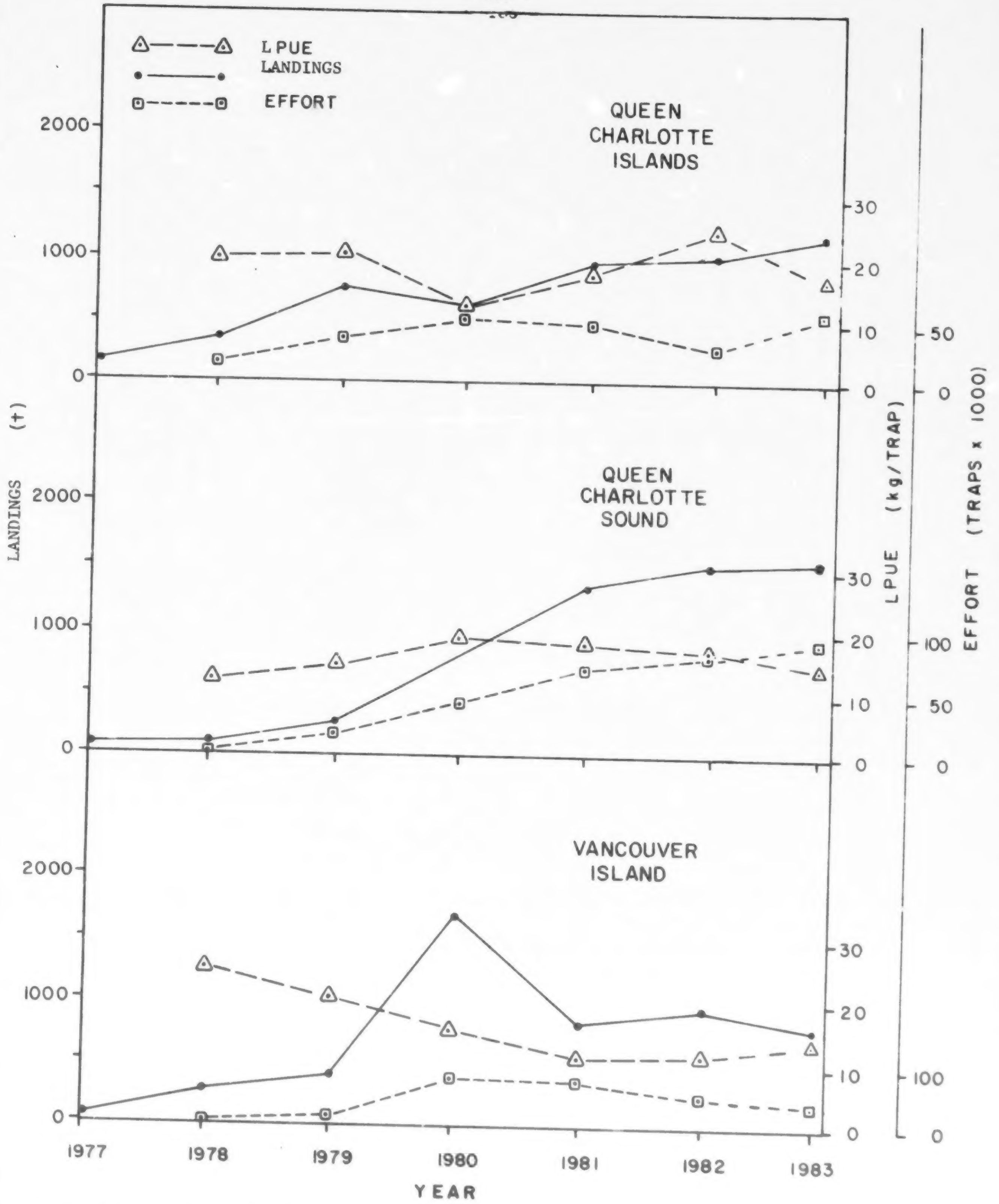

Fig. 5.1.2. Trends in landings and LPUE for the Canadian trap fishery for sablefish in the major fishing areas, 1977-1983.

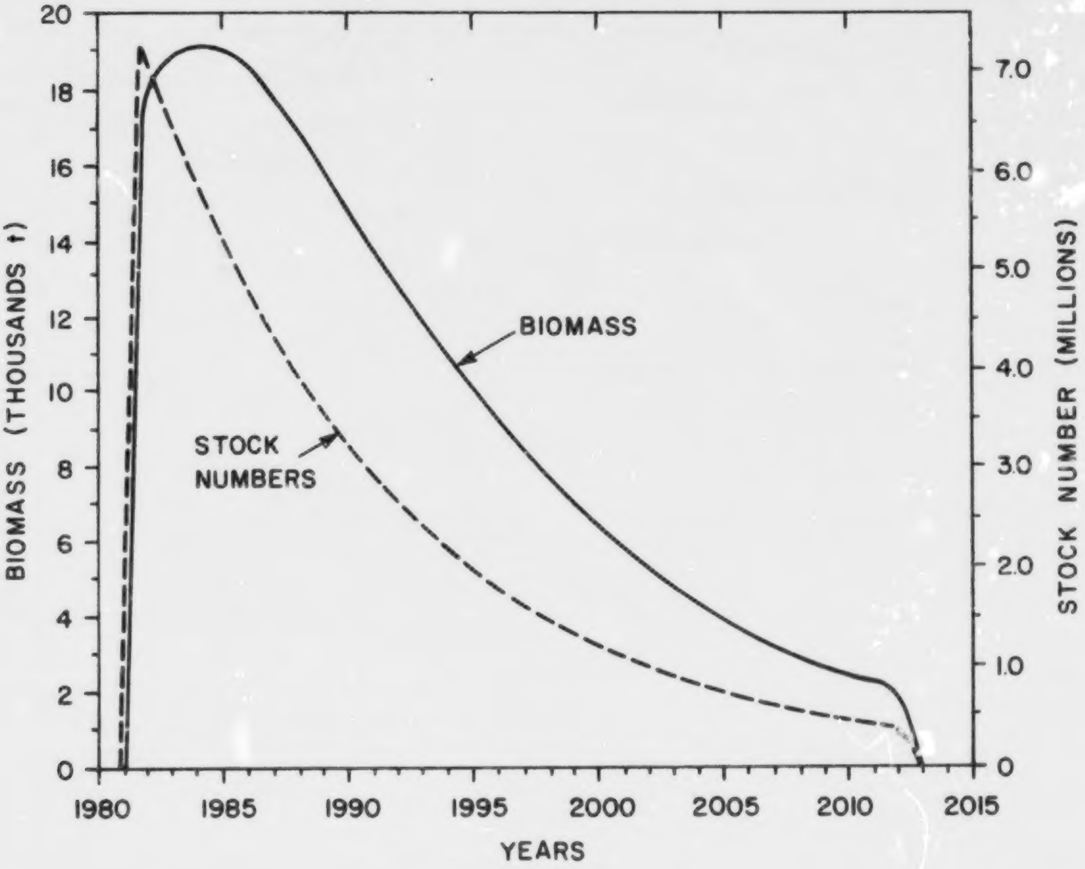

Fig. 5.1.3. Forward simulation of total biomass and population numbers of the 1977 sablefish cohort (M = 0.1) using a recruitment level of 8.23×10^6 age 4 fish. Fishing mortality was set F = 0.0.

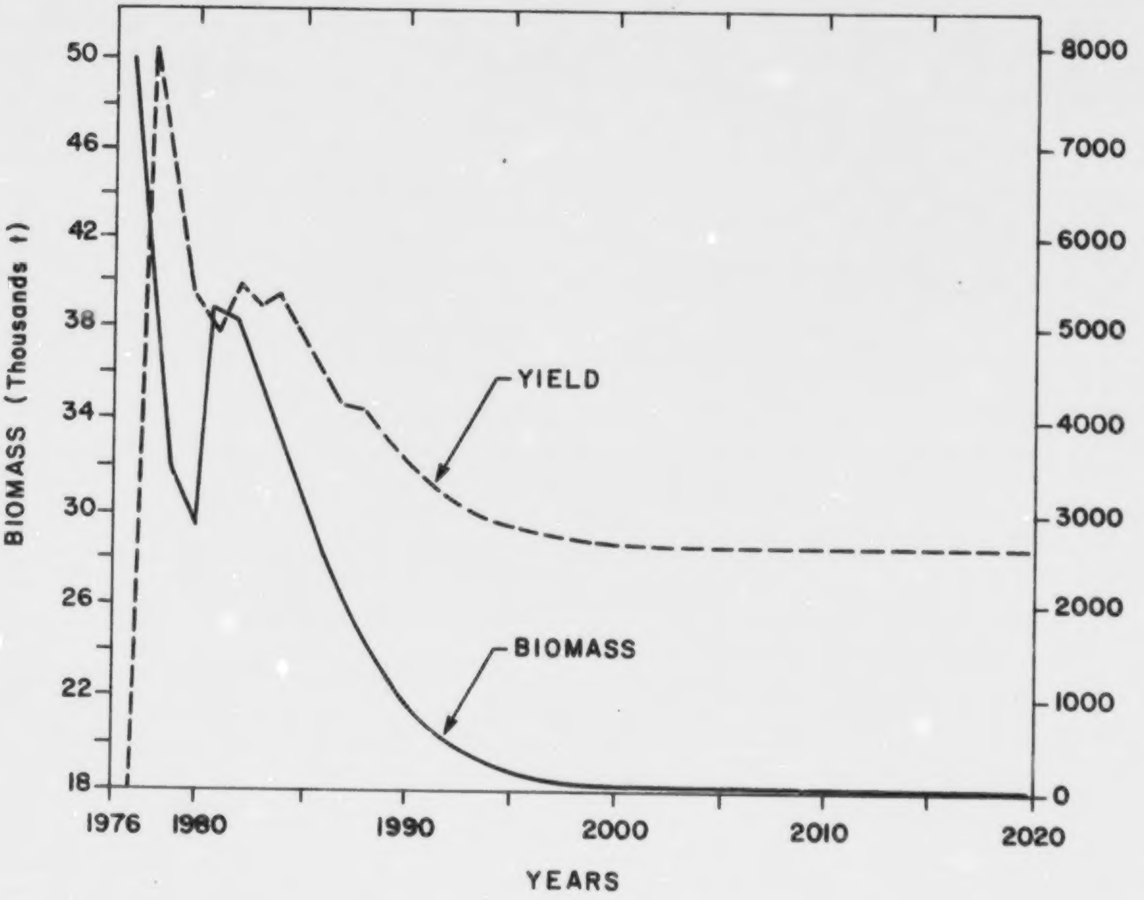

Fig. 5.1.4. Forward simulation of total biomass and yield using a recruitment level of 1.41 × 10^6 age 4 fish from 1983-2020. Fishing mortality was set F = 0.2.

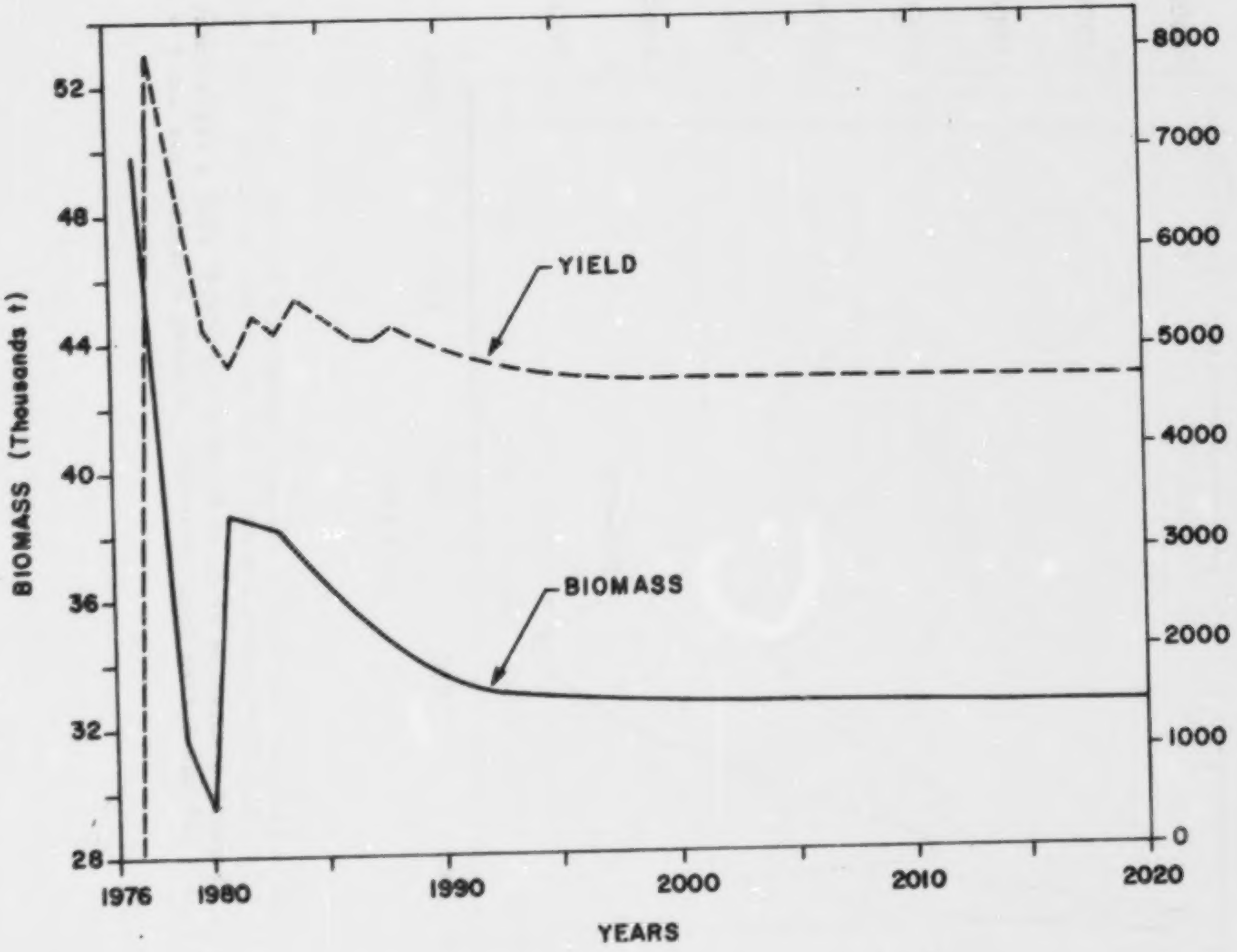

Fig. 5.1.5. Forward simulation of total biomass and yield using a recruitment level of 2.54×10^6 age 4 fish from 1983-2020. Fishing mortality was set F = 0.2.

6. Pacific hake

6.1. Coastwide. Yield options are not proposed on a coastwide basis

6.2. Strait of Georgia

by G. A. McFarlane and W. Shaw

6.2.1. General

The developing Canadian fishery for offshore hake provided a stimulus for exploitation of resident stocks in the Strait of Georgia. Even though Pacific hake in the Strait of Georgia are smaller, they are free of the parasite Kudoa paniformis which is responsible for the rapid degradation of the flesh of offshore hake (Kabata and Whitaker 1981). The absence of this parasite and the proximity of the stocks to land-based processing make this a potentially attractive fishery. In addition, there is a potential for harvesting roe (Tsuyuki pers. comm.) since large concentrations of spawning fish are available.

Pacific hake are now recognized as the most abundant resident fish in the Strait. The recent fishery takes place from February to June on spawning and post-spawning aggregations.

6.2.2. Landing statistics

Landings from the Strait of Georgia have increased dramatically from 516 t in 1979 to 3099 t in 1983 (Table 6.2.1). During 1984, an estimated total of 3483 t were landed from the Strait as of June 30. The fishery is carried out exclusively by midwater trawlers, mainly in the open Strait. The majority of catches have been from Minor Areas 14, 17 and 29. Since 1982, catches were predominantly from Minor Area 17 (Table 6.2.1). CPUE remained relatively stable in 1982 and 1983, dropping from the high 1981 level (Table 6.2.2). Preliminary estimates in 1984 have increased to 7.51 t/hr.

6.2.3 Stock assessment

Hake in the Strait of Georgia constitute a distinct population and are much smaller than offshore hake (Fig. 6.2.1). The shape and size of the otolith and the pattern of annuli formation is distinctive. Strong year classes present in the offshore hake (Beamish and McFarlane in press) are not synchronous with those of the Strait of Georgia hake. In addition, the absence of the myxosporean parasite K. paniformis, (Kabata and Whitaker 1981) clearly indicates the absence of interchange with the offshore population.

Within the Strait of Georgia there are discrete stocks. For example, a small stock of larger hake has been found in spawning condition In the Gulf Islands area 4-6 months prior to main spawning (Beamish et al. 1976). A stock of actively spawning hake has been found northwest of Texada Island, near Montgomery Bank (McFarlane et al. 1983). Small groups of hake have been observed in other areas such as mainland inlets and it is suspected that these constitute distinct local stocks. These small local stocks have not yet been exploited.

Pacific hake in the Strait of Georgia grow rapidly up to the age of 4, but at a slower rate than shown by the "offshore" hake (Fig. 6.2.1). Male and female hake show similar annual growth up to age 4 or 5, after which mean lengths for females are significantly larger (t-test $p \geq 0.05$). Mature males average 2-3 cm smaller than mature females. Both males and females continue to live for long periods during which little growth occurs.

The oldest fish was 20 yr but between 80 and 90% of the fish from research and commercial catches were in the range of 4-13 yr, except in 1983 when the strong 1981 year class contributed 22% to the catches (Fig. 6.2.2).

The catch curves indicate that there has been a substantial increase in the abundance of year classes since 1970 (Fig. 6.2.3). The reason for the increase in abundance is unknown.

Most (95%) adult hake range from 40-50 cm. Until 1982, the modal length of hake was 44 cm, dropping to 40 cm in 1983. This reduction in average size is attributed to the recruitment of the strong 1978 and 1979 year classes. In addition, these year classes are exhibiting slightly slower growth rates.

Preliminary estimates of abundance of adult hake ranged from 100,000 to 200,000 t based on hydroacoustic surveys carried out in the mid-1970s (Dr. F. Taylor pers. comm.) and ichthyoplankton surveys in 1979 (Dr. J. Mason pers. comm.).

During 1981, three methods--swept volume trawl surveys, hydroacoustic surveys, and ichthyoplankton surveys--were employed to determine the abundance of Pacific hake. Surveys were carried out in the entire Strait, but emphasis was placed on the spawning population present in the south central portion of the Strait. The results of the study (Mason et al. unpublished) will form the basis for future management of hake. Preliminary estimates from the swept-volume trawl surveys and hydroacoustic surveys ranged from 85,000-130,000 t (Thompson and McFarlane 1982) and 40,000-150,000 t (Kieser 1983), respectively. These estimates are lower than the earlier hydroacoustic estimates.

The Pacific hake fishery in the Strait of Georgia was not initiated until 1979, therefore no historical data base is available with which to study possible effects of the fishery on the stocks. The initial management approach was to utilize estimates of unexploited biomass (Bo) from hydroacoustic and swept-volume surveys during the mid-1970s, and estimates of instantaneous natural mortality rates (M) (0.45-0.63) to calculate theoretical maximum sustainable yields.

Using the Gulland (1970) formula, $MSY=0.5(M)(Bo)$, gave estimates ranging from 11,000-38,000 t. As these were preliminary parameter estimates, it was recommended that the total allowable catch not exceed 10,000 t until a re-assessment of abundance estimates and other biological parameters was undertaken.

Recent studies have suggested that the value 0.5 from the above formula is somewhat high and a more conservative value of 0.4 would be better (Gulland 1983a,b). Using recent estimates of abundance (60,000-130,000) and mortality (0.19-0.29) (McFarlane and Beamish 1983), the range in MSY is 4600-15,000 t. Assuming abundance is near the mid-point of the estimates

(100,000 t) obtained from the recent swept-volume midwater trawl and hydroacoustic surveys, and that mortality is in the range of estimates taken using changes in relative abundance of good year classes (0.19-0.29), then MSY is 7,600-11,600 t.

Estimates of MSY presented here may not represent the long-term average if there are large cycles in population size. Since the response of the stock to exploitation in terms of growth, survival or reproductive potential cannot be assessed at this time, a conservative management strategy should continue until the combined effects of recruitment fluctuations and fishing are determined. Because female hake produce a number of non-viable eggs that are resorbed, it is possible that a fishery will reduce the virgin stock which may result in increased fecundity. This increase in egg production per adult could conceivably result in increased yield.

6.2.4 Recommendations

A yield option with yields not exceeding 10,000 t is recommended. As catches begin to approach this level, monitoring of the fishery will allow us to re-assess our estimates. A yield option at a high risk level could be as high as 15,000 t, however the reproductive response of the stock to exploitation must be carefully monitored.

Table 6.2.1. Pacific hake landings (t) for the second quarter and whole year by Minor Areas 14, 17 and 29, and Major Area 4B during 1977-1983.

Region	1977		1978		1979		1980		1981		1982		1983	
	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr
Minor Area														
14	0	0.04	-	-	-	-	0	385.0	447.5	523.1	-	-	53.0	53.0
17	-	-	0	0.7	483.8	484.3	-	-	76.4	182.1	1927.0	2420.4	2185.7	2216.9
29	-	-	0.02	0.1	1.8	1.8	0	5.4	810.2	1434.1	0	11.6	0	11.2
Major Area														
4B	0	0.04	1.3	1.5	485.6	516.3	0.5	508.4	1363.7	2408.6	1927.1	2823.8	3055.7	3098.9

Table 6.2.2. Pacific hake landings, CPUE and effort from the Strait of Georgia (major Area 4B), 1977-1983.

Year	Total catch (t)	CPUE[a] (t/hr)	Effort[b] (hr)
1977	0.04	0.00	0.00
1978	2.00	0.00	0.00
1979	516.00	10.207	51.00
1980	508.00	4.583	111.00
1981	2409.00	8.937	2.70
1982	2824.00	4.769	592.00
1983	3099.00	4.465	697.00

[a] CPUE @ 25% qualification level.

[b] Effort = Total catch/CPUE.

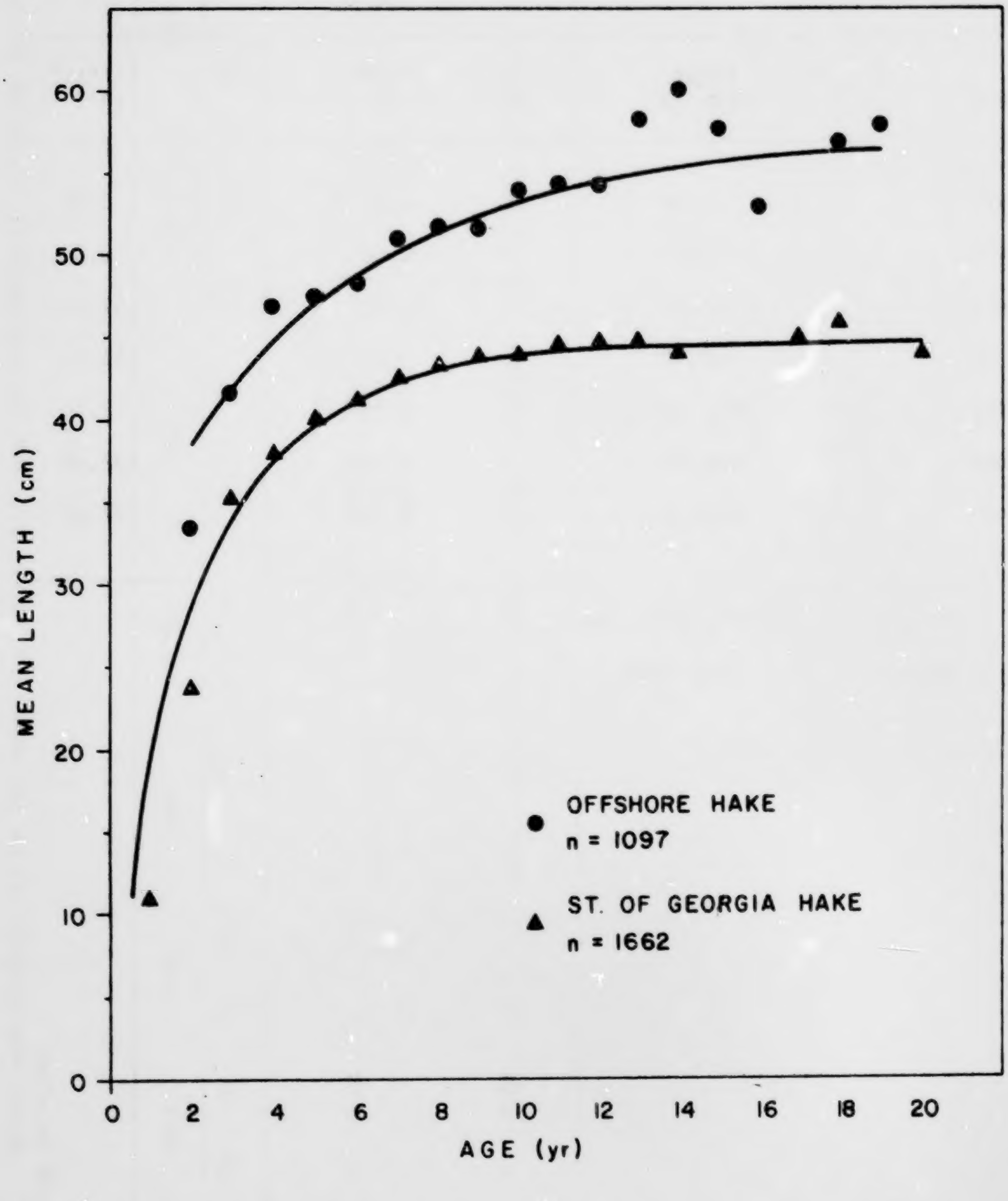

Fig. 6.2.1. Mean lengths at age from Strait of Georgia and "offshore" Pacific hake. Solid lines derived from the von Bertalanffy growth equation with parameters of $t_0 = -0.173$, $K = 0.457$, $L_\infty = 44.5$ cm; and $t_0 = -3.043$, $K = 0.233$, $L_\infty = 56.9$ cm for Strait of Georgia and "offshore" Pacific hake, respectively.

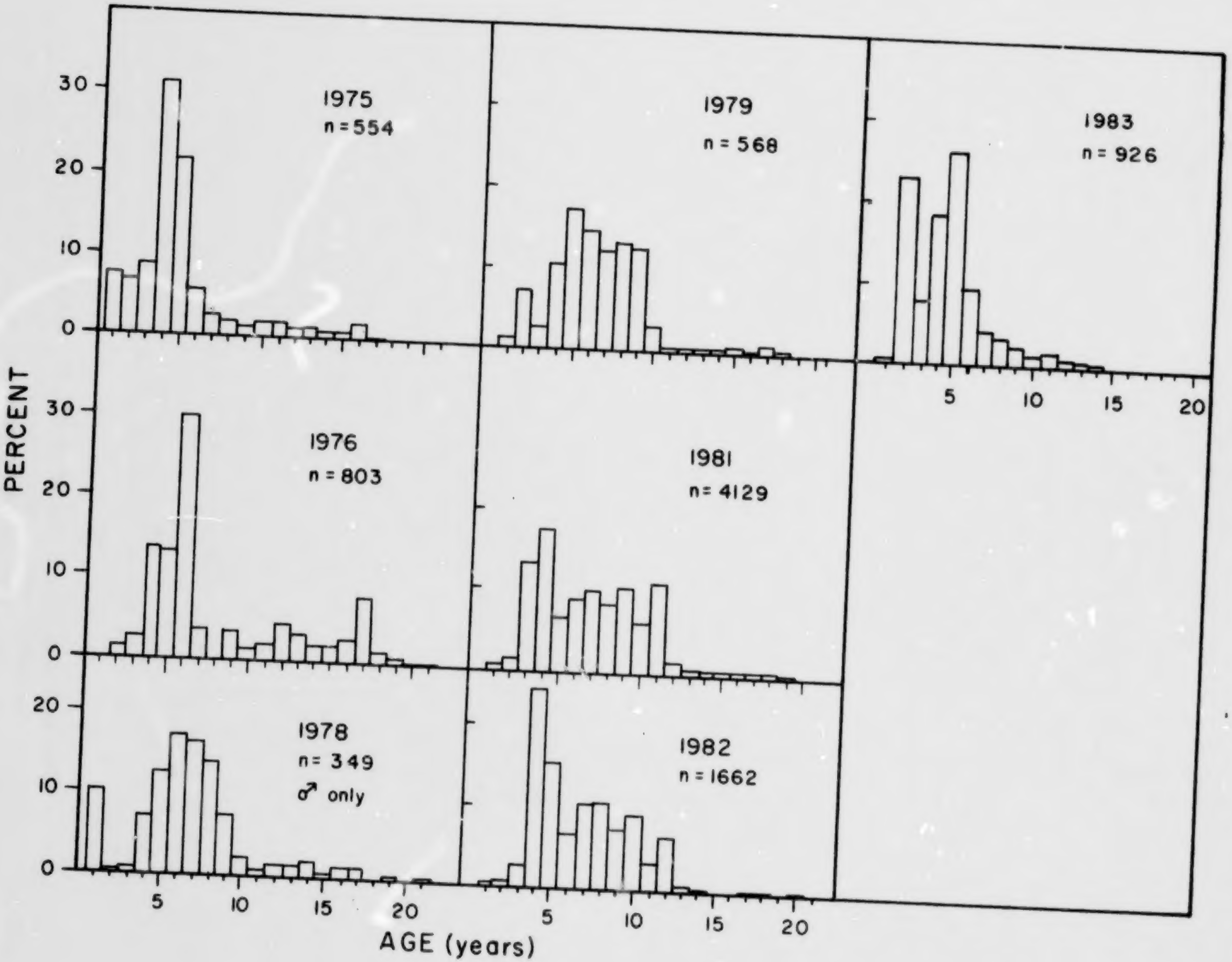

Fig. 6.2.2. Age frequency of Pacific hake in the Strait of Georgia (1975-1983) showing the persistence of the strong 1970 year-class until 1982 and the contribution of the 1979 and 1981 year-classes in 1983.

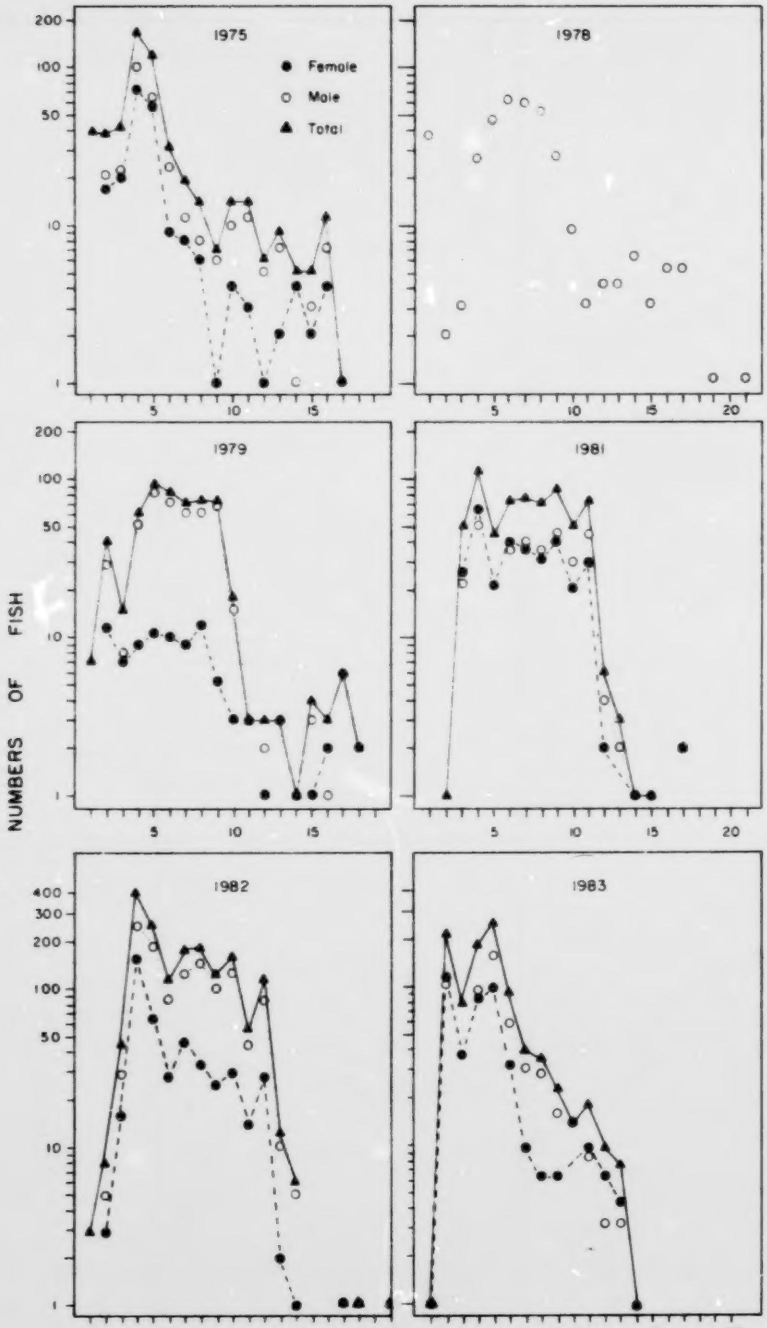

Fig. 6.2.3. Comparison of catch curves for Pacific hake in the Strait of Georgia from 1975, 1978, 1979, 1981 to 1983, showing the progress of strong year-classes through the fishery.

6.3. West coast of Vancouver Island by G. A. McFarlane and R. C. Francis[a]

6.3.1. General

Offshore Pacific hake (Merluccius productus) are mostly migratory fish that enter the Canadian zone in late spring and leave in the fall. It has been the target of a large foreign fishery that began in 1966. Since 1968, the largest landings in the groundfish fishery on Canada's west coast have been Pacific hake. Prior to 1978, the USSR caught the major percentage of hake in the Canadian zone, with Poland and Japan accounting for much smaller quantities. After 1977 and the declaration by Canada of an extended fishing zone, the commercial fishery was divided into a domestic, joint venture, and foreign fisheries. These fisheries are now the most rapidly developing fisheries on Canada's Pacific coast.

6.3.2. Landing statistics

Reported landings by all nations in the Canadian zone (Sub-zones 5-1 and 5-2) has fluctuated from a high of 64,959 t in 1969 to a low of 5,191 t in 1977 (Fig. 6.3.1). Pacific hake stocks off the west coast of Vancouver Island have been fished by Canadian fishermen since 1978. Most of the catch is sold directly to foreign processor vessels. Canadian landings, as part of a joint venture fishery with foreign fishermen, have increased dramatically from 1,814 t in 1978 to 27,656 t in 1983 (Table 6.3.1).

6.3.3. Stock assessment

Until recently, the size of the offshore Pacific hake stocks and estimates of yield were determined by U.S. scientists. A TAC for the Canadian zone was established based on the U.S. estimate, and an estimate of the proportion of fish that move into the Canadian zone. Work conducted by Canadian and U.S. scientists in the late 1970s and early 1980s led the Canada-U.S. International Groundfish Committee to recommend that cooperative research programs which examine the relationships between the Canadian and U.S. fisheries for hake be undertaken. Furthermore, the results of these studies should be used to develop joint management alternatives. This work was conducted in 1982 and 1983 and the results are summarized in this document. This material is presented in more detail in Francis et al. (in prep.).

The fishery in Canadian waters generally starts in July or early August. Total landings for both Canadian and U.S. fisheries are presented in Table 6.3.2. In all areas the fishery usually ends in mid to late October with the offshore and southerly movement of the fish back to the winter spawning grounds.

The distribution of landings by INPFC area for 1977 to 1982 is presented in Figure 6.3.2. Recently the largest removal has been from the INPFC Columbia Area (with the exception of 1982 when the fishery was forced north due to a preponderance of small unmarketable fish south of the INPFC Vancouver Area).

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The age at which most fish are first recruited to the U.S. fishery is 2 or 3 years, whereas most fish are recruited at age 5 or 6 to the Canadian fishery. Figures 6.3.3 and 6.3.4 give the relative age frequencies of catches in U.S. (1973-1982) and Canadian (1976, 1978-1982) waters respectively. Table 6.3.3 gives the estimated total (U.S. + Canada) catch at age for 1977 through 1982. Strong year classes clearly dominate the fisheries in both U.S. and Canadian waters (Table 6.3.4). Currently, the 1970, 1973, and 1977 year classes are dominant in the fishery. In 1982 these three year classes accounted for 59% and 76% of the estimated catches by age in the U.S. and Canadian zones respectively. Indications are that the 1980 year class (Dark, pers. comm.), not yet fully recruited to either the U.S. or Canadian fisheries, may be one of the strongest year classes ever observed in the fishery. During the history of the fishery, strong year classes have occurred in 1980, 1977, 1973, 1970, 1967 or 1968, 1964, and 1961 (Beamish and McFarlane 1983). Bailey (1981, 1982) and Bailey and Francis (1983) report that conditions during the first few months of life are critical in determining year class strength.

A comparison of the mean size of males and females from the 1970 year class sampled in the U.S. and Canadian commercial fisheries from 1976 through 1982 shows that not only do larger, older fish tend to occur in the Canadian fishery, but the individuals of any particular year class tend to stratify on a north-south gradient by size, with larger fish of both sexes tending to occur farther north. In addition, females dominate the catch in the Canadian zone, ranging from 60% to 82% of the catch since 1977.

Estimates of stock biomass are obtained in the triannual NMFS trawl/hydroacoustic groundfish survey of the west coast region (Dark et al. 1980; Nelson and Dark 1983). Table 6.3.5 gives estimates of stock biomass by INPFC statistical area for the two comprehensive surveys run and reported to date (1977, 1980).

The most common indirect method for estimation of available stock biomass is cohort analysis using a time series of catch at age data. Francis (1983) describes a weighted cohort analysis procedure used for hake. Table 6.3.6 gives the results of the cohort analysis updated to include catch at age data through 1982. This provides the basic parameters for the age-structured management model results reported here.

A stochastic model developed by Getz and Swartzman (1981) was modified and applied to Pacific hake (Swartzman et al. 1983). Modifications included

1) Incorporation of environmental effects on recruitment, and
2) Development of a management policy algorithm which sets quotas in such a way as to use strong year classes in a practical and efficient manner while protecting the stock when it is in poor condition and environmental conditions do not appear to be conducive to stock improvement in the immediate future.

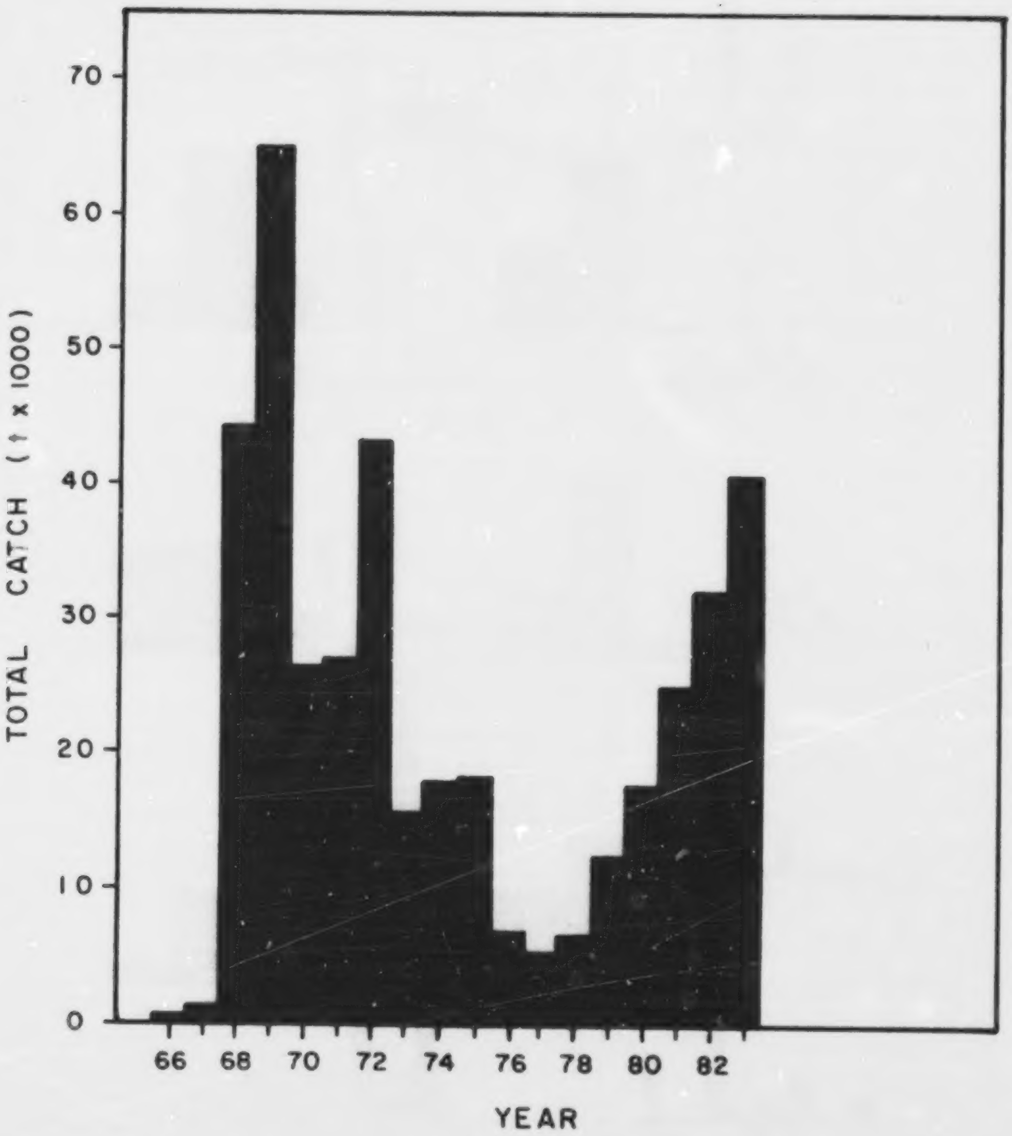


Fig. 6.3.1. Histogram--All-nation catch off Canada 1966-1983.

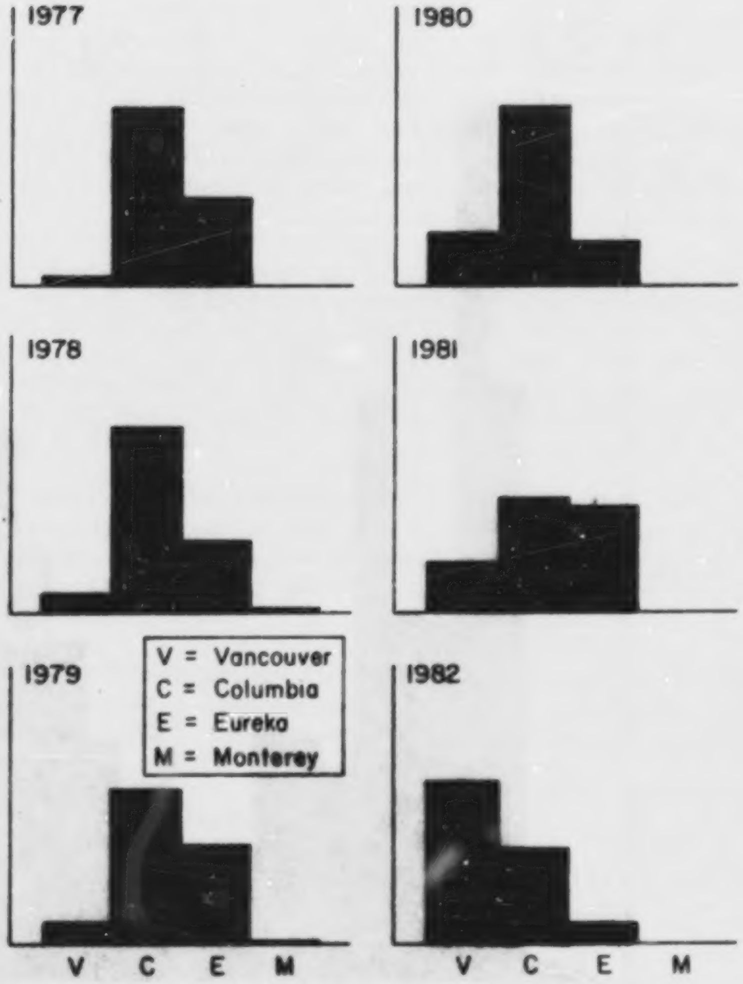


Fig. 6.3.2. Relative distribution of Pacific hake catch in weight by INPFC Area.

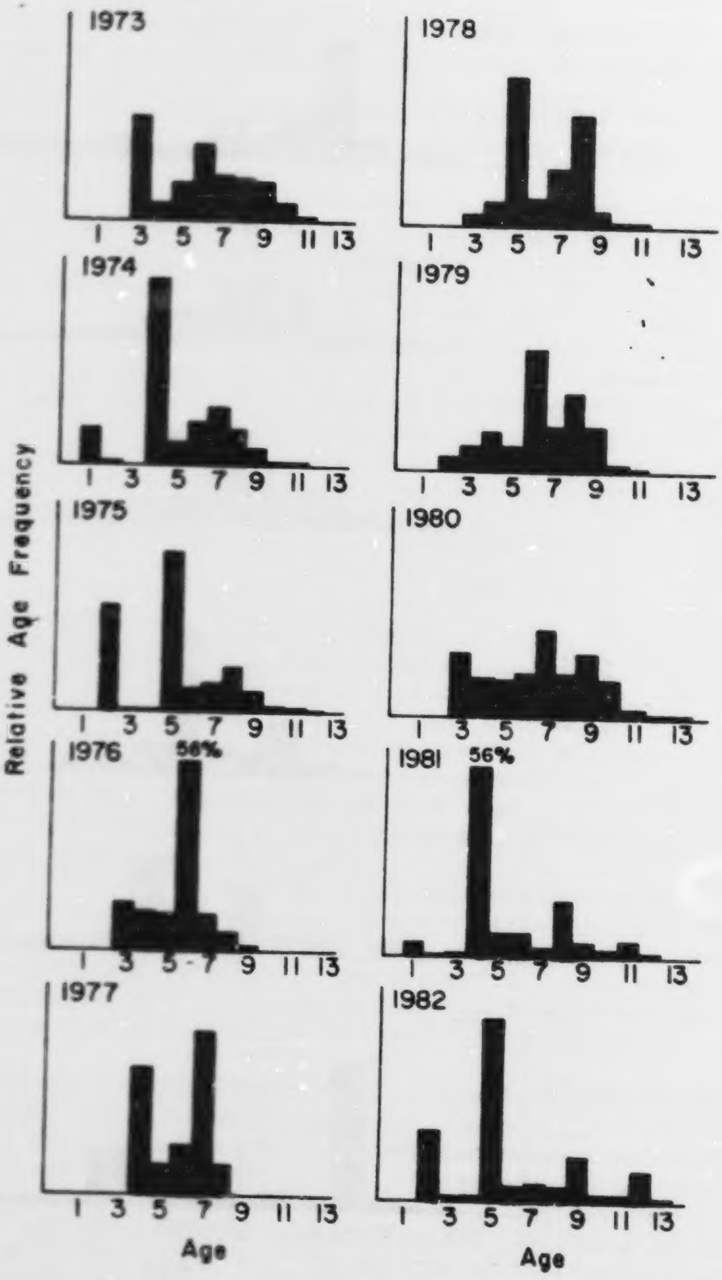


Fig. 6.3.3. Relative age-frequency of Pacific hake catch in U.S. waters.

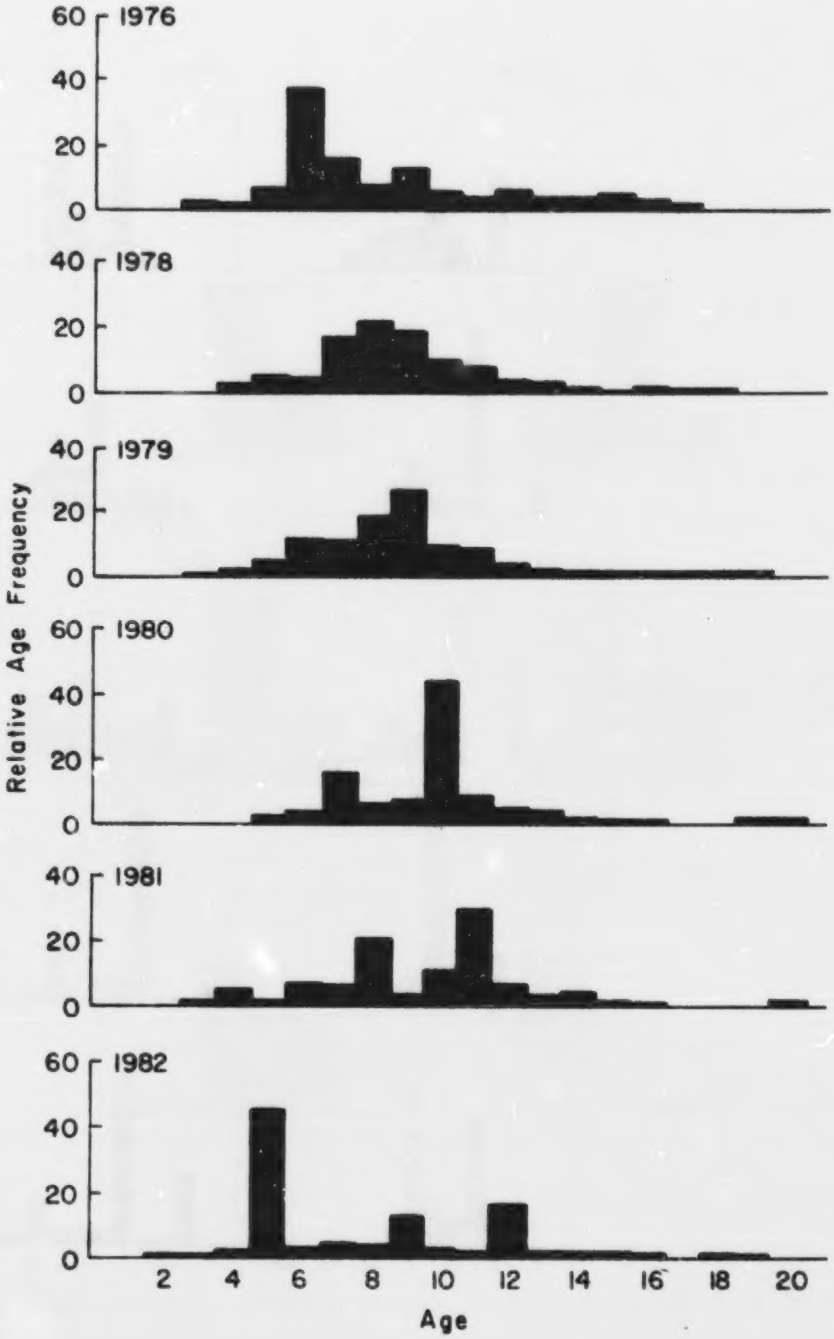


Fig. 6.3.4. Relative age-frequency of Pacific hake catch in Canadian waters, 1976, 1978-82.

Both the population/fishery model and the management algorithm were further refined to

1) Divide the fishable stock into separate substocks available to fishing in U.S. and Canadian waters;
2) Allow effort to be divided between U.S. and Canadian waters;
3) Increase the number of age-classes from 8 to 12 in order to include fish older than age 11;
4) Incorporate information on egg production as a function of individual fish weight to produce an egg index to replace fecund stock biomass in the recruitment functions;
5) Replace the stock-recruit probability transition matrix with means and variances of recruitment for given levels of egg production; and
6) Redefine the state of the system from a probability vector of numbers at age to a mean and variance of numbers at age.

The management algorithm has been modified to include an objective function which is to be maximized, and to protect the older (mostly Canadian) stock as well as the total stock from collapse in the event of a sequence of low recruitment years. This new algorithm has the option of either dual control by U.S. and Canadian fisheries managers or simultaneous control as before. A detailed description of these modifications is given by Swartzman et al. (in prep.). Sensitivity of model performance to parameters and constraints used in the analysis are discussed in detail in Swartzman et al. (in prep.).

Both the original single stock and the split stock version of the model were examined. Application of the model can be separated into four modes: historical, equilibrium, management and stock projection. In the historical mode, long-term runs of the model are made over a historical time series of environmental conditions at the time of spawning and under various values of model parameters. Simulated and observed time series of both landings and stock biomass are compared and the most realistic parameter values chosen. In the equilibrium mode, runs are made under constant long-term environmental conditions. Both equilibrium yields and stock biomasses are estimated. In the management mode, attempts are made to systematically vary effort over the same environmental time series used in the historical runs to maximize long-term yield or CPUE while minimizing annual variations in stock, yield, and effort. In the projection mode, model estimates of the condition of the stock are replaced by the current best estimate of the stock to enable evaluation of short term managment strategies.

In management application of the model, parameters were developed for both the single stock and split stock options. The managment algorithm combines an objective function related to yield with boundary constraints which operate over a planning horizon (5 years). In general terms, the management algorithm provides a simulation of fishing at various levels of effort. The number of different effort combinations is limited by boundary constraints established by the user. For the purpose of this evaluation, the constraints include: minimum reproductive stock levels, minimum level(s) of LPUE, and upper and lower limits on effort.

For a given year of a simulation, effort is initiated at the level which produced MSY and then systematically increased or decreased to isolate that value of total effort (or combination of U.S. and Canadian effort) which maximizes the objective function without violating any of the boundary constraints. The manner in which effort is increased or decreased over the 5-year planning horizon depends on whether effort is above or below some critical level determined from the equilibrium yield analysis. In this evaluation, the objective function maximizes yield in the next simulated year subject to the boundary constraints holding for 5 years into the future (e.g. set effort to maximize 1984 yield subject to the stock and CPUE remaining greater than minimum level and effort remaining below a maximum for 1984-88). In the case of the split stock runs, U.S. and Canadian stocks are weighted equally.

Definition of management objectives can take many forms and must be set by fisheries managers themselves. We attempted to provide insight to Canadian and U.S. fisheries managers as to the likely consequences of contemplated decisions. In order to evaluate these possibilities, we examined model estimates of yield, effort, CPUE, average and minimum stock biomasses, along with their corresponding variances under a variety of possibly management strategies. The results of these analyses are discussed in Francis et al. (in prep.).

In general, management implications to the Canadian and U.S. fisheries, based on this analysis can be summarized as follows.

1) There is a large amount of variability in hake production, a good deal of which seems to be a function of environmental conditions acting on early life history stages of the animal. Francis et al. (in prep.) indicate a 4- to 8-fold difference in year class production between favourable and unfavourable environmental conditions.

2) The concept of equilibrium yield is rather meaningless for Pacific hake due to the year-to-year variability in environmental conditions which affects the production of successful year classes.

3) Two hundred thousand tons appears to be an upper limit for long-term average catch (Canada and U.S.) from the offshore hake resource. However, this maximum could only be attained by varying catch from year to year, taking advantage of strong year classes when they appear by increasing yields to levels substantially greater than 200,000 tons and, similarly, reducing yields when the stock is in poor condition.

4) In order for the Canadian fishery to maintain itself at average annual catch levels greater than 30,000 tons, the U.S. fishery cannot maintain average annual catch levels greater than 160,000 tons. If the U.S. fishery harvested at average annual catch levels equal to the present U.S. MSY (175.5 tonnes), the Canadian fishery would be driven to economic extinction, in the long run, due to significant reductions in LPUE.

5) The stock is in relatively good condition at the present time (mid-1984). This is due to the relatively low catches since 1977. Assuming that the 1980 year class was extremely large, the management policy discussed in Francis et al. (in prep.) indicates that between 300 and 400 thousand tons (Canadian and U.S. yield) could be harvested from the total resource in 1984 without doing any long-term damage to the productive capacity of the stock.

Current status

In order to examine management strategy for 1985, using the model described here, the most current information must be used. Our analysis indicates that the current status of the older stock is very good due to a recent history of relatively low exploitation in the U.S. fishery, whereas the younger stock may require protection in the immediate future. Indications are that the 1980 year-class is very large, but that the 1981-1983 year-classes may be small. It is presently too early to comment on the magnitude of the 1984 year-class. Therefore, the hake fishery will rely totally on the previous strong-year classes (1980, 1977, 1973) for the next several years.

The biomass from the 1983 Canada-U.S. hydroacoustic trawl survey is 1.330 million t (Francis pers. comm.), compared to 1.537 and 1.197 million t in 1980 and 1977, respectively, indicating little change in absolute biomass.

However, in 1983, 38% of the stock was estimated to be in the INPFC Vancouver Area, whereas 29% and 22% were in that area during 1977 and 1980, respectively.

In addition, both length and weight at age were reduced during 1983 and 1984 (preliminary). Based on both Canada and U.S. weight at age data, it is apparent that year-classes normally expected to exhibit significant growth were substantially reduced (Table 6.3.7.). This decrease in average length and weight at age is possibly related to the 1982-83 El Nino event and is expressed as a reduced growth rate as well as northward shift in distribution of smaller fish at age.

As a result of the above information, 1985 projections were made using two sets of average-weights at age: (1) the weights used in previous projections and (2) the weights observed in the 1983 fishery (Table 6.3.7.). 1985 projections were examined assuming cold years (poor recruitment) for 1981-84. The management algorithm of Francis et al. (1984) was then run for 1985 assuming both warm and cold year recruitment for the 1985 year-class.

Mean values of single and split stock projections are given in Table 6.3.8. Each line of the table is the mean of four model runs: (1) optimistic 1980 recruitment (XWR), warm (good) year recruitment in 1985 (W85), (2) XWR, cold (poor) year recruitment in 1985 (C85), (3) average warm year recruitment in 1980 (AWR), W85, and (4) AWR, C85. These four runs present a range of options for the 1980 and 1985 year-classes which we feel are a realistic reflection of what we know about them. Unfortunately, sensible split stock runs could not be made for the 1983 weight-at-age option due to the manner in which the model wanted to split the stock (due to the reduced weight at age, the model, with its existing parameters, distributed stock biomass heavily into the U.S. zone, whereas, the 1983 survey showed just the opposite. Therefore, U.S. scientists estimated the split stock runs based on an analysis of variance approach (Total catch = (131)(311)/215 = 190).

Recommendations

The 1985 yield options are presented in Table 6.3.8. At the end of Table 6.3.8. we present our best estimate of what the 1985 yield should be. These turn out to be the mean values between the single and split stock runs prorated to the U.S. and Canadian fishing zones according to the mean prorations from the split stock runs. The split stock version indicates that the catch could be weighted more heavily towards Canada. In this version, U.S. effort is applied fairly uniformly across the population age structure whereas Canadian effort is applied disproportionately to the older age classes. Thus, the split stock will allow for continuation of Canadian fishery where the older stock is in good condition but the younger stock is not. Using this analysis we recommend a yield option for Canada of 67,000 tonnes for 1985. However, because of the concern of overestimation of the biomass estimate from hydroacoustic surveys and the reduction in size at age, this must be considered a high risk option. Until these effects are fully investigated, management of the resource should lean on the side of conservatism, and a conservative yield option of 45,000 t is recommended.

It is apparent that both Canada and the U.S. can benefit from cooperation in developing management strategies for the Pacific hake fishery. Cooperation can be partial (protection of stock) or total (protection of stock and maximizing overall yield in both fisheries). Both Canadian and U.S. managers must decide on both short and long term objectives for this fishery. Once these objectives have been arrived at, the management algorithm described here and in more detail in Francis et al. (in prep.) can provide insight into both long term and year to year strategies.

Table 6.3.1. Total landings (t) of hake by foreign and domestic fishery off Canada (Area 3C) during 1978-1983.

Year	Nations	Total landings (t)			
		National	Joint venture	Domestic	Total
1978	Poland	589	1,814		
	USSR	700	0		
	Japan	3,364	0		
	Total	4,653	1,814	6,467	
1979	Poland	4,263	3,102		
	USSR	0	1,131		
	Japan	3,637	0		
	Total	7,900	4,233	302	12,435
1980	Poland	4,456	4,560		
	USSR	78	4,300		
	Japan	817	0		
	Greece	0	3,355		
	Total	5,351	12,214	96	17,661
1981	Poland	3,189	4,779		
	USSR	227	7,342		
	Japan	187	0		
	Greece	0	4,927		
	Total	3,603	17,048	4,440	25,091
1982	Poland	10,357	10,222		
	USSR	0	9,391		
	Japan	2,237	0		
	Total	12,594	19,613	2	32,209
1983	Poland	13,177	13,464		
	USSR	0	14,192		
	Total	13,177	27,656	0	40,833

N.B. Catches reported in this fishery cannot be verified by weight tallies, as domestic catches are.

Table 6.3.2. Annual catches of Pacific hake (10^3t) in U.S. and Canadian waters and estimates of effort (1000 standard days) for total fishery, 1966-82.

	U.S.				Canada						
Year	For.	J.V.	Dom.[a]	Total	For.	J.V.	Dom.	Total	Total[b]	LPUE[c]	Effort
1966	137.0			137.0	0.7			0.7	137.7	19.2	7.171
1967	195.1			195.1	1.3			1.3	196.4	33.0	5.951
1968	68.0			68.0	44.3			44.3	112.3	10.8	10.397
1969	109.1			109.1	65.0			65.0	174.1	17.9	9.726
1970	202.2			202.2	26.4			26.4	228.6	24.9	9.180
1971	147.5			147.5	26.7			26.7	174.2	19.7	8.842
1972	111.6			111.6	43.4			43.4	155.0	21.0	7.381
1973	144.8			144.8	15.7			15.7	160.5	23.9	6.752
1974	209.3			209.3	17.9			17.9	227.2	26.1	8.705
1975	201.9			201.9	18.2			18.2	220.1	18.9	11.646
1976	230.8			230.8	6.7			6.7	237.5	25.7	9.242
1977	127.2			127.2	5.2			5.2	132.4	31.2	4.244
1978	96.8	0.9		97.7	4.5	1.8		6.3	104.0	34.9	2.980
1979	114.9	8.8		123.7	7.9	4.2	0.3	12.4	136.1	25.8	5.276
1980	44.0	27.6		71.6	0.0	17.5	0.1	17.6	89.2	28.3	3.152
1981	70.4	43.6	0.0	114.1	3.1	17.5	4.4	25.0	139.1	28.3	4.915
1982	7.1	67.5	1.0	75.6	11.3	20.9	0.0	32.2	107.8	30.9	3.489

([a]) 1966-1980 from Bailey et al. (1982).

([b]) 1966-1981 from Bailey et al. (1982) for U.S. fishery.

([c]) Estimated assuming LPUE (Canada) = LPUE (U.S.).

Table 6.3.3. Landings in numbers (millions) of Pacific hake by age off the west coast of the U.S. and Canada 1973-1982.

Age	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
01	31.517	-	-	-	-	-	-	-	7.769	-
02	-	1.401	87.127	0.329	1.812	-	6.232	-	1.107	27.438
03	55.891	1.051	2.650	36.822	3.905	4.124	8.986	14.825	1.769	1.941
04	9.673	161.438	3.644	29.260	54.469	8.038	14.560	8.721	106.910	2.069
05	21.711	22.062	126.219	29.589	11.297	48.228	8.731	8.897	10.389	71.525
06	40.198	38.171	21.533	185.097	20.180	9.320	44.775	9.920	12.165	5.785
07	25.151	47.626	23.190	27.617	69.779	20.185	16.502	22.612	6.498	7.549
08	23.001	27.665	37.435	13.808	11.551	37.187	29.058	10.415	27.807	6.752
09	21.497	12.257	16.895	4.932	6.281	6.274	19.684	15.711	7.521	16.975
10	10.318	3.852	7.288	0.986	3.127	2.862	3.704	14.199	6.522	3.426
11	4.514	1.751	3.644	0.329	1.842	1.527	2.242	3.398	14.508	3.491
12	1.935	1.051	1.325	-	1.076	0.605	0.659	1.878	3.091	11.039
13	1.075	0.350	0.331	-	0.340	0.310	0.681	1.199	1.112	0.800
14	-	-	-	-	-	0.086	0.168	0.196	1.028	0.541
15	-	-	-	-	-	-	0.123	-	0.245	-

1973-1976: From reported Polish age composition (Jackowski 1980).

1977-1982: U.S. and Canadian observer samples.

Table 6.3.4. Contribution (% landing by number) of the strong 1970, 1973, and 1977 year-classes to the Pacific hake fisheries in the U.S. and Canadian zones.

	Year-class	1976	1977	1978	1979	1980	1981	1982
U.S.	1970	57	38	27	12	8	4	4
	1973	10	30	36	30	21	13	10
	1977	-	-	-	4	16	56	45
	Total	67	68	63	46	45	73	59
Canada	1970	36	-	22	26	44	29	19
	1973	3	-	6	11	16	21	14
	1977	-	-	-	-	-	5	43
	Total	39	-	28	37	60	55	76

Table 6.3.5. Distribution of Pacific hake biomass (10^3 t) from two Northwest and Alaska Fisheries Center trawl-hydroacoustic surveys from INPFC Monterey Area north.

		INPFC Area				
Year	Source	Vancouver	Columbia	Eureka	Monterey	Total
1977	Midwater	343.821	316.440	360.944	108.087	1,129.292
	Bottom	6.560	32.917	9.501	18.266	67.244
	Total	350.381	349.357	370.445	126.353	1,196.536
1980	Midwater	322.225	260.477	182.783	578.841	1,344.436
	Bottom	17.286	20.156	11.481	143.824	192.747
	Total	339.621	280.633	194.264	722.665	1,537.183

Target strength = -35 db.

Table 6.3.6. Input data and summarized results of Pacific hake cohort analysis.

Year	Recruitment at age 3 (billions)	Effort (10 days)	Age	Total q	M
1973	2.350	6.752	3	0.00184	0.278
1974	0.717	8.705	4	0.00932	0.210
1975	0.344	11.646	5	0.01501	0.195
1976	0.936	9.242	6	0.03108	0.257
1977	0.184	4.244	7	0.04343	0.357
1978	0.221	2.980	8	0.08482	0.457
1979	0.156	5.276	9	0.09132	0.557
1980	2.374	3.152	10	0.14954	0.657
1981	0.081	4.915	11	0.14954	0.757
1982	0.212	3.489			
Mean	0.758				
CV	117.149				

Table 6.3.7. Average weight at age (kg.) of Pacific hake in the U.S. and Canadian fishery zones.

	Francis et al. (1984)			1983 Data		
Age	U.S.	Canada	Combined	U.S.[a]	Canada[b]	Combined
3	0.443	-	0.443	0.351	0.434	0.366
4	0.545	-	0.545	0.422	0.482	0.452
5	0.644	0.791	0.663	0.506	0.551	0.541
6	0.729	0.904	0.769	0.590	0.618	0.612
7	0.798	0.977	0.855	0.670	0.700	0.691
8	0.853	1.095	0.947	0.726	0.751	0.745
9	0.898	1.183	1.023	0.750	0.767	0.761
10	0.933	1.228	1.078	0.780	0.794	0.790
11	0.962	1.286	1.134	0.812	0.820	0.817
12	0.985	1.377	1.205	0.849	0.876	0.867
13	1.000	1.377	1.219	0.920	0.937	0.931
14	1.007	1.377	1.233	1.011	1.026	1.022
15+	1.007	1.377	1.233	1.137	1.137	1.137

[a] 1983 fishery - 3 year running mean.

[b] 1983 Vancouver area fishery - 3 year running mean.

Table 6.3.8. Mean values of single and split stock yield projections for 1985.

Stock option	Growth option		Yield (1000 t)	Effort (1000 d)	CPUE (t/d)
Single	Francis (1984)		215	4.8	44.8
	1983 Data		131	3.7	35.4
Split	Francis (1984)	Tot	311	10.6	29.3
		U.S.	213	4.3	49.5
		Can	98	6.3	15.6
	1983 Data	Tot	190	Note: This is an estimate	
		U.S.	130	of what these model runs	
		Can	60	might produce.	
1985 yield options		Tot	212		
		U.S.	145		
		Can	67		

7. DOGFISH

by M. W. Saunders

7.0.1. General

Introduction

The spiny dogfish (Squalus acanthias) in the northeastern Pacific Ocean are found from Alaska to California. Tagging studies indicate the presence of three stocks, one offshore stock ranging from Alaska to California and two inshore stocks, one in Puget Sound and a second in the Strait of Georgia. Preliminary tagging results (McFarlane et al. 1982) suggest that movements within the Strait of Georgia are extensive and complex. The degree to which mixing of offshore and inshore stocks occurs may be greater than previously thought (McFarlane and Beamish, in press) due to low effort offshore and a high degree of non-reporting.

The history of the dogfish fishery is a long and turbulent one. During the late 1800s and the early 1900s dogfish liver oil was used for lighting and lubrication. During the 1940s and 1950s, the dogfish liver, because of its high vitamin A content, was highly prized and consequently dogfish ranked within the top several fisheries with respect to landed value over those years. The 1950s saw the collapse of the demand for vitamin A and dogfish became regarded largely as a nuisance. During the period 1959-1975 a total of 11 subsidized fisheries took place, the major aim of which was to reduce dogfish abundance below problem levels.

Commercial longline and trawl fisheries have developed from the mid-1970s to the present in response to food fish markets developing abroad. The food fishery peaked in 1979 and is presently hampered by fluctuating markets and depressed economic conditions world-wide.

7.1. Coastwide (not including Strait of Georgia)

7.1.1. Introduction

The offshore stock of dogfish ranges from Alaska to California with centers of abundance off the southwest coast of Vancouver Island and in Hecate Strait. Dogfish are most abundant during the spring and summer in the shallows and are believed to migrate both offshore and southward during the winter months. Significant catches were taken from the stock during the 1940s, however recent removals have been small and the stock remains underexploited.

7.1.2. Landing statistics

Estimates of catch from 1876-1982 have been made and reported by Ketchen (in press). Fishing was most intense during the years of the vitamin A liver fishery from 1941-1949, with a peak of 49,000 t landed coastwide in 1944.

Landings from the present food fish fisheries peaked at 2439 t in 1980. Catches dropped to 388 t in 1981, rose to 1318 t in 1982, and dropped again to 627 t in 1983 (Table 7.1.1).

Catches are mainly trawl (Table 7.1.1) and from Major Statistical Area 3C. The only other offshore area with significant landings is Hecate Strait (Area 5D) with trawl landings of 242 and 272 t in 1980 and 1982 respectively.

The majority of dogfish are landed during the first and second quarters (Table 7.1.2). The landings are made by larger trawl vessels that are capable of fishing offshore during this period. During second quarter catch rates are sufficiently high to make the fishery viable even at low market prices. Although the fish appear to be abundant during the third quarter, a large number of trawl vessels are fishing with the cooperative hake venture at this time.

7.1.3. Stock assessment

The dogfish is a long-lived, slow-growing fish with a reproductive potential that is limited by low fecundity, late maturity and a long gestation period (Ketchen 1972, 1975). The unique biology and the absence of a continuing fishery render traditional stock assessment models inappropriate. Consequently, Wood et al. (1979) developed a deterministic age-structured model that incorporates information regarding catch, growth, maturity, and fecundity and using a fecundity survival matrix model (Leslie 1945) to compute future populations. Compensatory change in the rate of natural mortality is the mechanism of density-dependent response (Wood et al. 1979). The relation of compensatory change in natural mortality to stock size is assumed to be linear.

Historical catch records provided by Ketchen (in press) have been incorporated and the model updated. Estimates of catch for inshore and offshore waters enable separate assessments of these two areas to be made but because of difficulties in separating earlier catches the inshore Strait of Georgia-Puget Sound complex is treated as a single stock.

The size of the offshore stock in 1943 has been estimated from the relation of fishing success to catch already taken during the liver fishery (1943-49) using Leslie and Davis's (1939) method including Braaten's modification (Ricker 1975) (Ketchen pers. comm.; Ketchen 1969). It is assumed that abundance (LPUE) was proportional to catch over this period. Starting stock sizes ranged from 323,000 to 453,000 t using the minimum and maximum estimates of catches (Ketchen in press). Figure 7.1.2 presents trends in the abundance of marketable size dogfish based on varying levels of compensatory mortality and starting stock sizes. The difference in abundance trends with minimum and maximum estimates of catch is small, therefore an average has been used in further abundance simulations.

The biomass of the marketable stock remained largely unaffected by the catch until the onset of the liver fishery in the 1940s (see Fig. 7.1.2). The heavy fishing during this period reduced the marketable biomass to approximately one-half of its original size. The model predicts recovery of the population by the mid-1960s and a decline to the present. This oscillation is not entirely the result of catches taking place during the 1960s and 1970s but is primarily due to extremely high catches during the 1940s and the influence this had on recruitment.

Juvenile dogfish inhabit the midwater, remaining segregated from the adult population (Beamish et al. 1982). The steady recruitment of juveniles, whose abundance was unaffected by the liver fishery is the reason for the observed recovery in the 1960s. The subsequent drop in abundance is due to the poor recruitment from age groups affected by the strong fishery.

Figure 7.1.3 shows the effect of various levels of sustained yield on the abundance of the marketable stock into the future, using average catch and a starting stock of 390,000 t. The oscillations set into motion by the liver fishery are maintained although significantly decreased in amplitude with time. Beyond catches of 14,000 t, the stock is unstable and by 16,000 t the stock cannot be maintained. At current catch levels (<5,000 t/yr) the biomass will continue to increase to the turn of the century.

Figure 7.1.4b summarizes runs completed for plausible values of compensatory mortality and starting stock size. The maximum sustainable yields at these levels of compensatory mortality are indicated by the graphed lines. At yields above the lines the stock is not stable over a one hundred year period.

A harvest strategy that could implement sustained effort would provide the most stability. Figure 7.1.5 shows the effect at three levels of fishing mortality (F) on abundance over the period 1982-2080. Most noticeable is a more rapid levelling of oscillations in abundance than with sustained yield.

Periodic or pulse fisheries will perpetuate the fluctuations in abundance with time seen resulting from the liver fishery.

7.1.4. Recommendations

Dogfish may be harvested on a sustained or periodic fishery basis.

A periodic fishery for dogfish perpetrates oscillations in abundance that vary in amplitude and period depending on the size and duration of the fishery. The number of possible combinations of catch size and duration are too numerous to consider, therefore it is recommended that periodic fisheries be evaluated at the time of their proposal.

A sustained fishery will also produce oscillations in abundance but they will decrease in size with time. Hence this strategy provides a steady supply while maintaining a stock size considerably lower than present nuisance levels. For removals from the offshore stock, including Alaska, British Columbia, Washington, Oregon, and California waters, up to 15,000 t may be considered low risk, and from 15,000 to 25,000 t high risk as a maximum sustainable catch. This range is based on alternative possible compensatory mortalities and starting stock sizes. We recommend a low risk sustainable yield option of 8,000 t be adopted for the Canadian zone, with a provision for taking up to 15,000 t while U.S. catch from the stock remains low. Joint Canada-United States management of both the offshore and Georgia Strait-Puget Sound stocks is advisable.

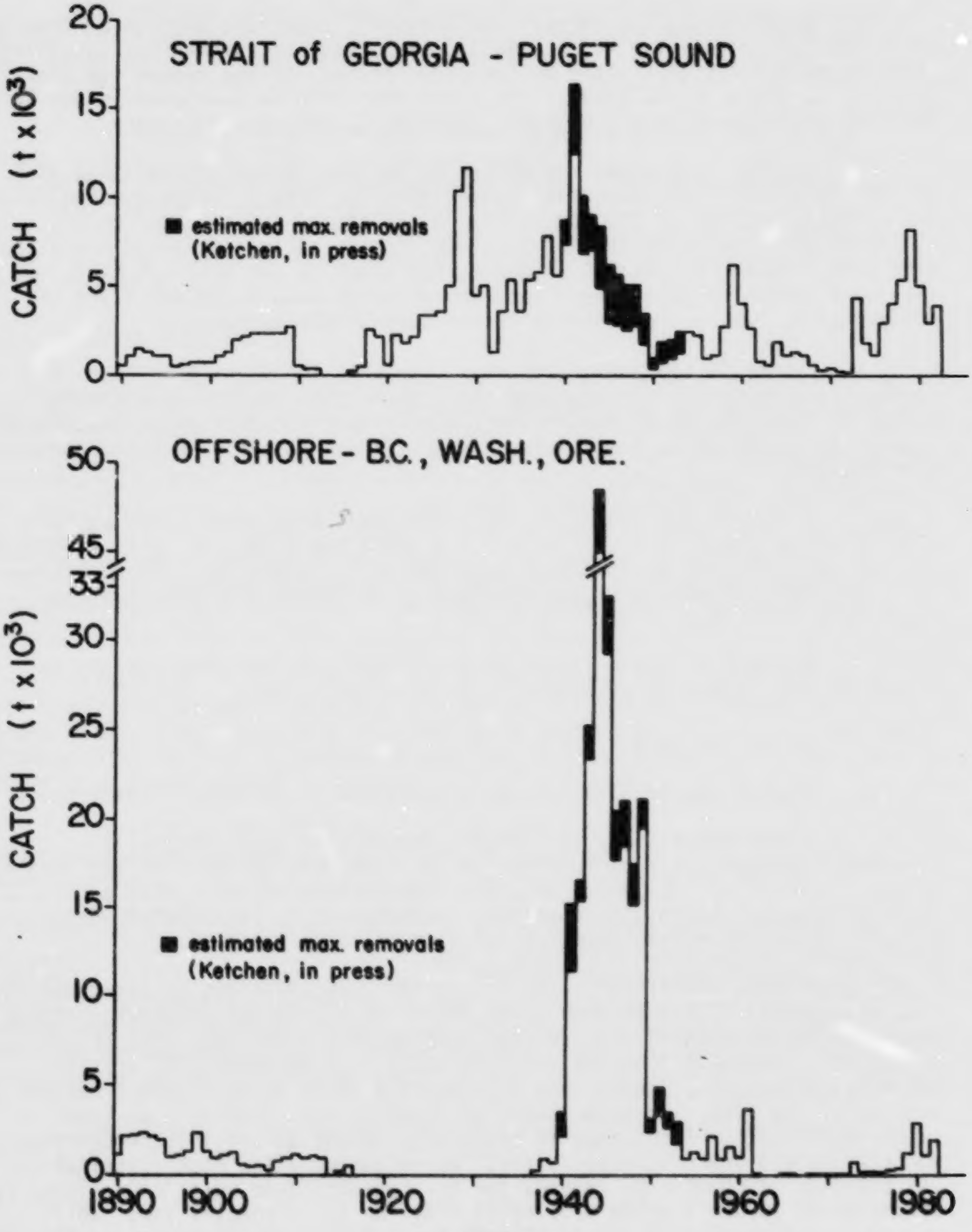


Fig. 7.1.1. Catches of spiny dogfish (t) from 1890 to 1982 all gears combined, for the Strait of Georgia-Puget Sound and offshore stocks.

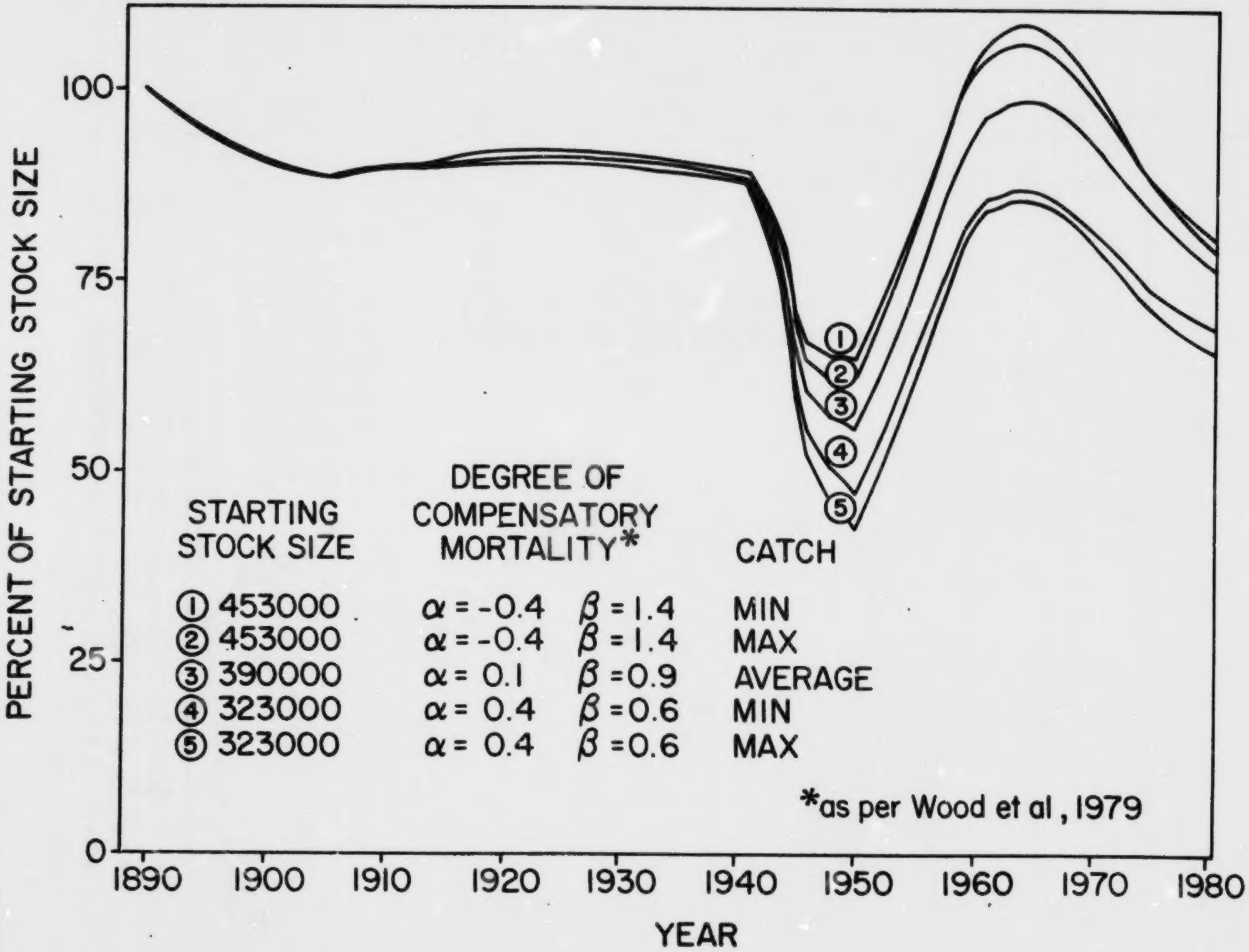


Fig. 7.1.2. Trends in abundance of spiny dogfish, offshore, for varying levels of catch, compensatory mortality and starting stock size.

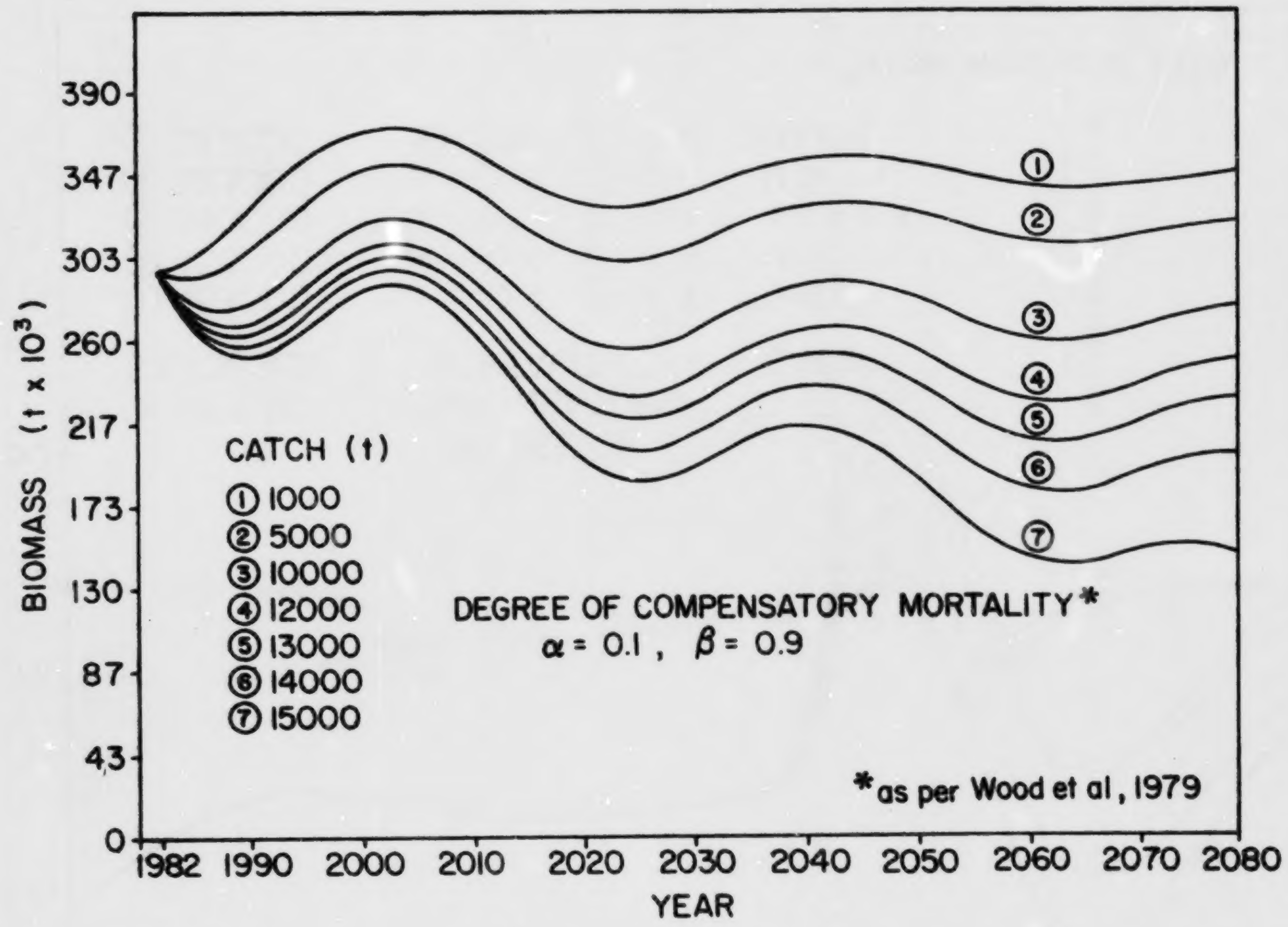
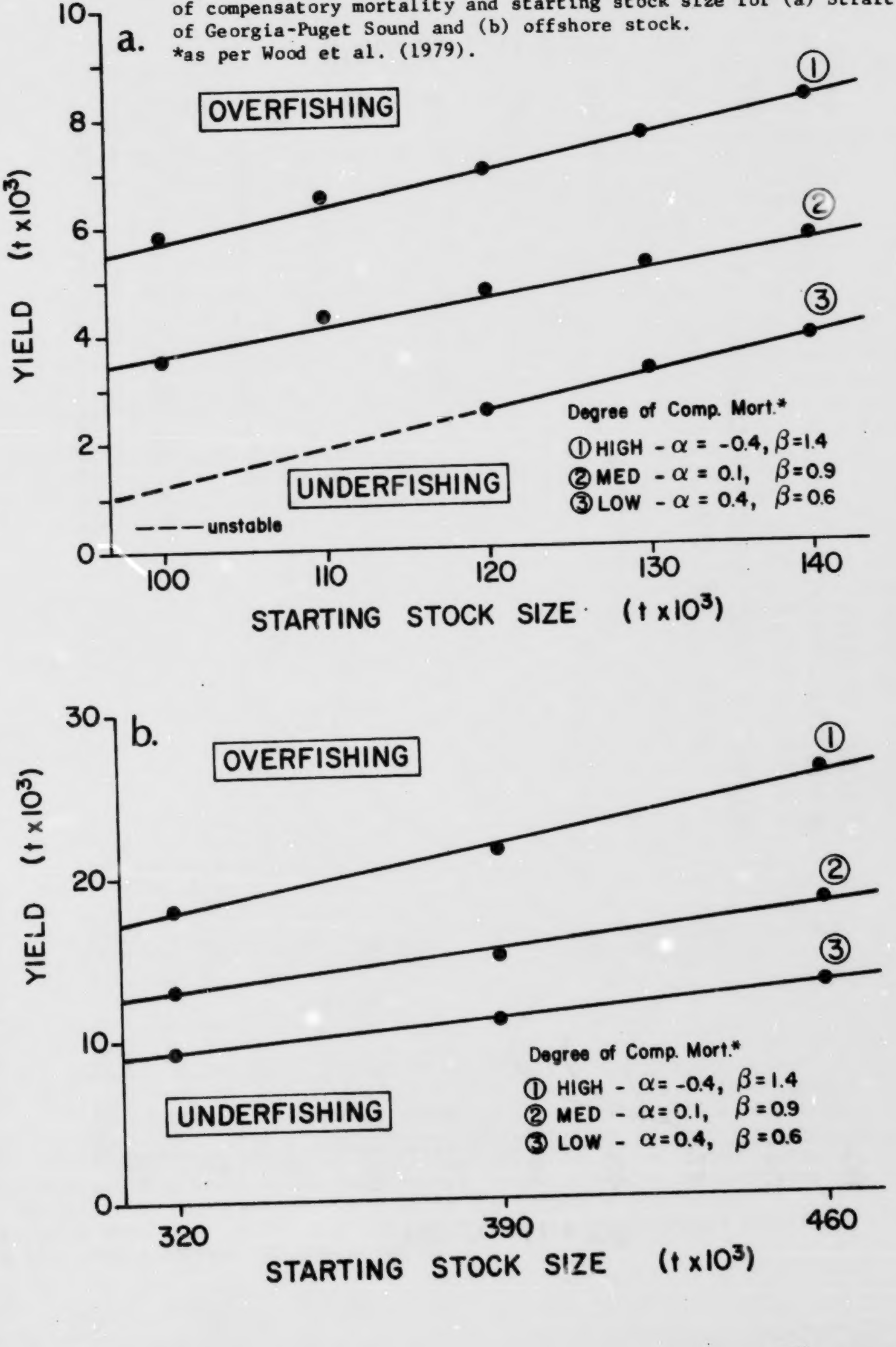


Fig. 7.1.3. Forward simulations of spiny dogfish abundance, offshore, at varying levels of sustained yield.

Fig. 7.1.4. Sustainable yields of spiny dogfish at varying levels of compensatory mortality and starting stock size for (a) Strait of Georgia-Puget Sound and (b) offshore stock.
*as per Wood et al. (1979).



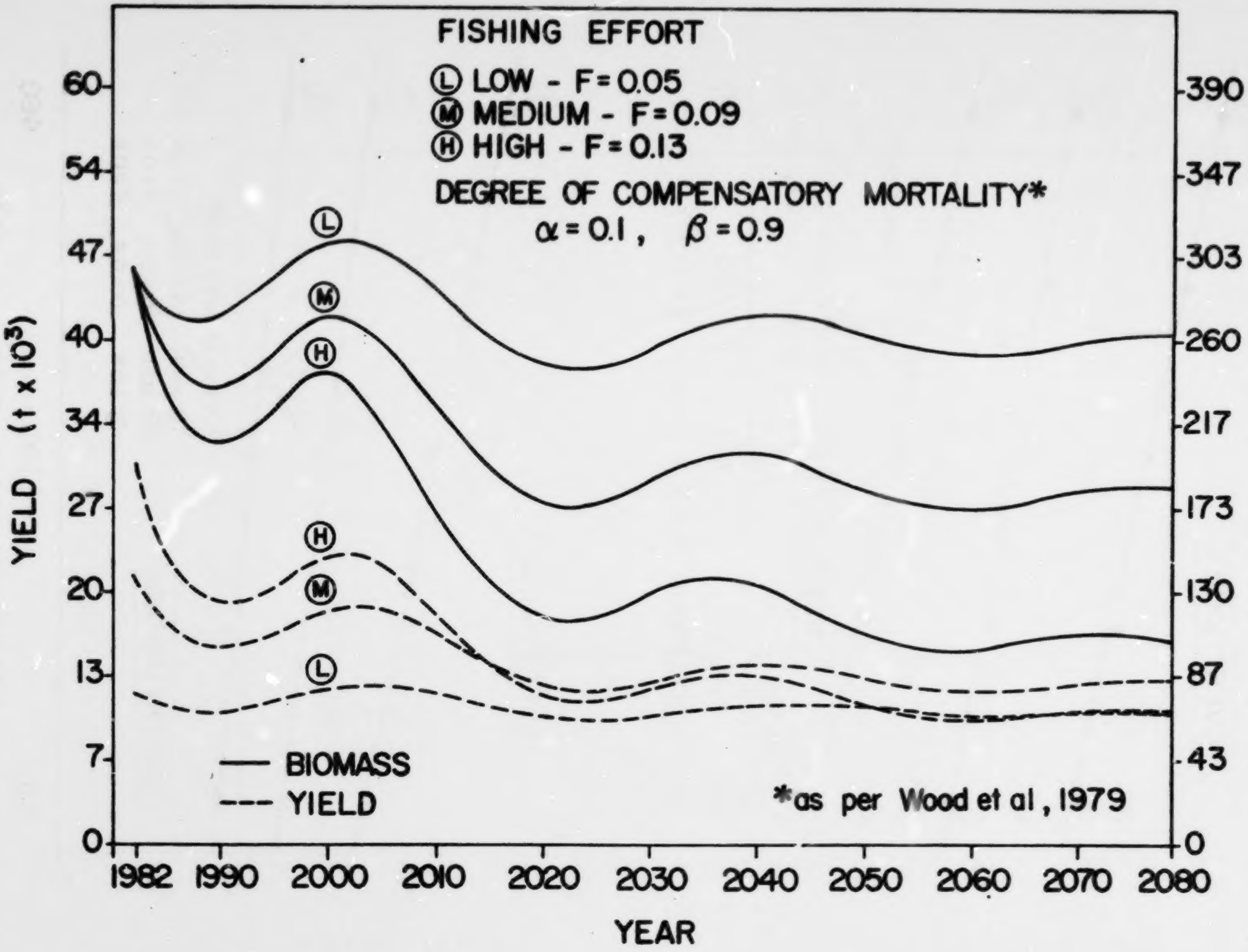


Fig. 7.1.5. Forward simulations of spiny dogfish abundance and yield offshore, at different levels of sustained effort.

7.2. STRAIT OF GEORGIA -- PUGET SOUND

7.2.1. Introduction

On the basis of earlier tagging studies, it is believed that dogfish in the Strait of Georgia and Puget Sound constitute separate stock(s) from the stock offshore. The degree to which mixing occurs both between Puget Sound and the Strait of Georgia and between inshore and offshore stocks remains unknown.

Large catches were taken during the 1940s' liver fishery and the stock is currently impacted by directed commercial trawl and longline fisheries for dogfish and to some degree, by incidental removals by recreational sports fisheries.

7.2.2. Landing statistics

Catches of dogfish from the Strait of Georgia-Puget Sound (Fig. 7.1.1) averaged 4,828 t over the period 1920-1949 and peaked in 1949 at 16,000 t. Catches remained low during the 1960s, and as markets developed, catches increased during the mid to late seventies.

In the Strait of Georgia (4B) landings are predominantly longline, accounting for 69.8% of the landings over the period 1979 to 1983 (Table 7.1.2). Fishing takes place during the first and fourth quarters of the year (Table 7.2.2) between the more lucrative salmon, herring, and halibut openings that these small boats often participate in.

Landings from trawl and longline food fisheries in the Strait of Georgia rose from 170 t in 1976 to a peak of 4,334 in 1979. Catches have averaged 1,338 t over the years 1980-1983 with a high of 2,104 t landed in 1980 and a low of 763 t landed in 1981.

The size of the incidental sports catch of dogfish is unknown although sports creel census data (Anon. 1982) for 1980-81 provides some indication. It was estimated that 724,000 sports fishing trips took place during 1980-81 over which the average catch was 0.24 dogfish per trip, indicating a total possible catch of 173,760 dogfish. Assuming the average length of a sports-caught dogfish is between 60-85 cm (0.762 and 2.313 kg) and that every dogfish caught is killed, the removals of dogfish could range between 130 and 390 t.

7.2.3. Stock assessment

The size of the stock present in the Strait of Georgia has been estimated to represent as much as one-third to as little as one-fifth of the offshore stock. Figure 7.2.1 presents predicted trends in abundance from 1890 to 1981 using a single level of compensatory mortality and historical catches applied to varying stock sizes. At starting stock sizes below 95,000 t, the stock could not have survived to the present. Assuming on the basis of area that the Strait of Georgia-Puget Sound could not sustain a population representing more than one-third of the offshore stock, the possible starting stock size ranges between 140,000-95,000 t.

Catches from the Strait of Georgia-Puget Sound stock have been considerably higher than catches from the offshore stock over the periods 1920-1940 and 1972 to the present (Fig. 7.1.1). Figure 7.2.2 presents trends in abundance for a single starting stock size and the effect that varying estimates of compensatory mortality and minimum and maximum estimates of historical catch size have on the predicted abundance. Again the model predicts the recovery of the stock by 1960 (Fig. 7.2.2). The decline in size during the late 1970s would help to explain anecdotal indications that abundance has been decreasing.

Future trends in abundance for the Strait of Georgia stock are, of course, similar to trends in abundance for the offshore stock, using the various harvest strategies. Differences occur in the time and size of fluctuating peaks in abundance, a result of differing historical catches. For instance, Figure 7.2.3 presents the trends in abundance for a single starting stock size at various levels of sustained yield. Abundance at any sustainable level is rising for the Strait of Georgia-Puget Sound stock at the present time while for all but the lowest levels of yield from the offshore stock, the abundance at present is decreasing (Fig. 7.1.2).

Again referring to Figure 7.2.3, abundance fluctuates, with the stock becoming unstable at levels of sustained yield above 4200 t. Figure 7.1.4a summarizes runs completed for all plausible values of compensatory mortality and starting stock sizes and presents the maximum sustainable yields that can be removed. Sustained effort (Fig. 7.2.4) produces the most stable harvest strategy.

7.2.4. RECOMMENDATIONS

Dogfish may be harvested on a sustained or periodic fishery basis. As previously discussed, periodic fisheries produce and perpetuate oscillations in abundance and should be evaluated with regard to their impact on the stock at the time of their proposal. Sustained fisheries provide the most stable harvest strategy.

The trends in inshore abundance presented can be viewed only qualitatively until questions regarding the degree of mixing between Puget Sound and Strait of Georgia stocks and the impact of sports fisheries have been answered and until a reliable estimate of absolute abundance is obtained for accurate calibration of model projections. Removals from the Strait of Georgia-Puget Sound stock that are in the range of 4000 t to 6000 t may be considered low risk, while removals in excess of 6000 t are high risk for maximized sustainability of catch. Assuming an even split in biomass between the Strait of Georgia and Puget Sound, we recommend a low risk option of 2000 to 3000 t be adopted for the Strait of Georgia -- the Canadian portion of the stock.

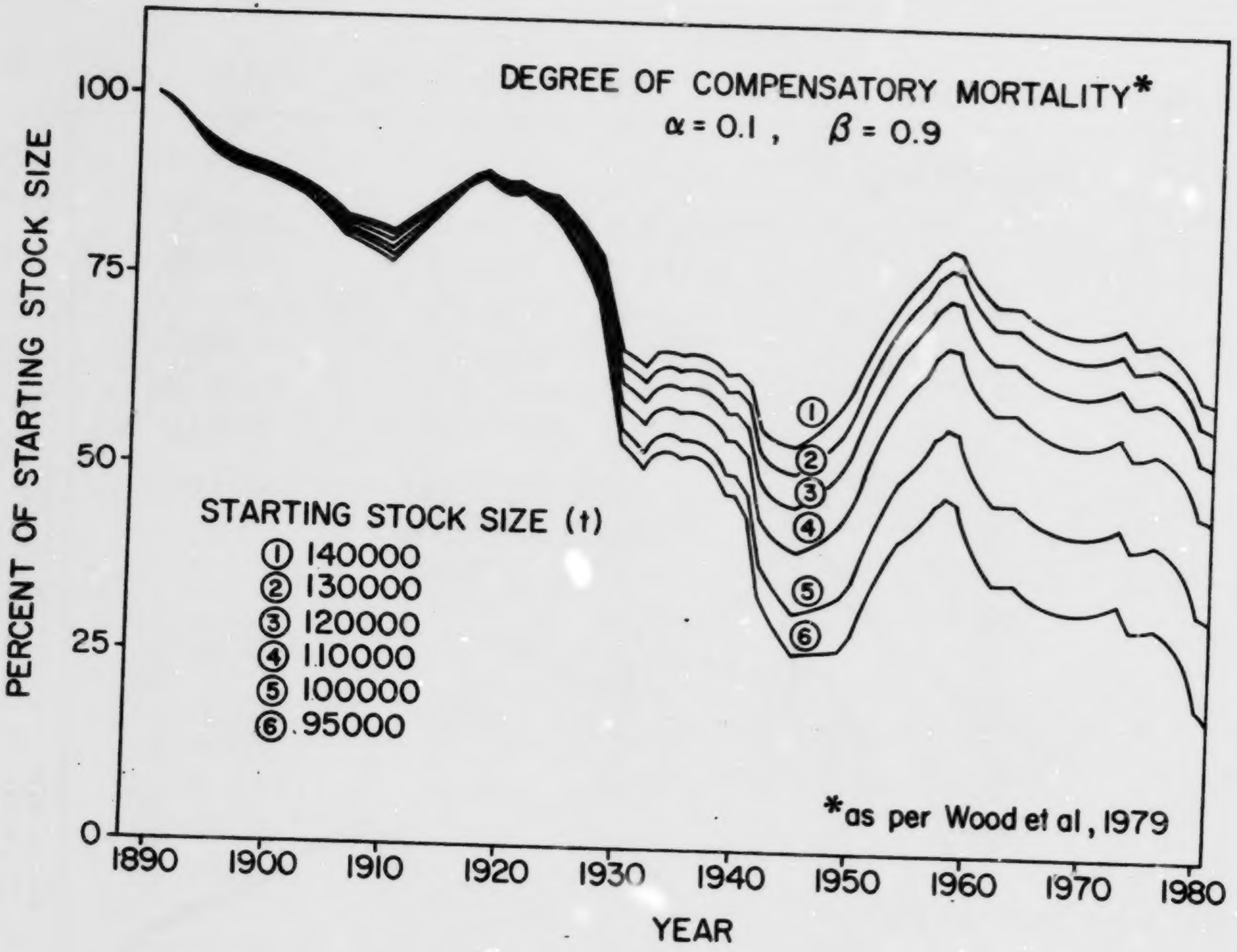


Fig. 7.2.1. Trends in abundance of spiny dogfish in the Strait of Georgia-Puget Sound with varying starting stock sizes.

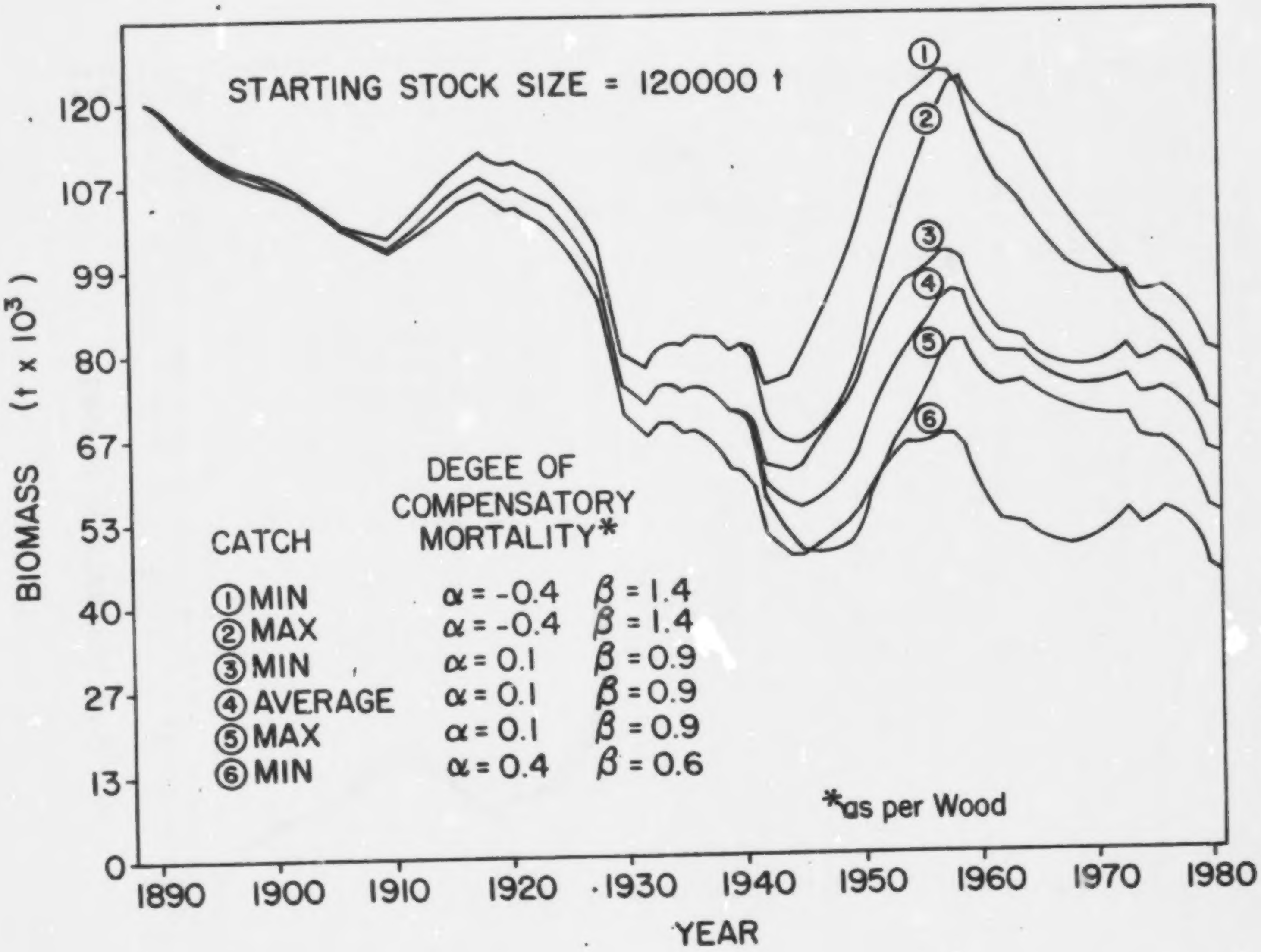


Fig. 7.2.2. Trends in abundance of spiny dogfish in the Strait of Georgia-Puget Sound using different levels of compensatory mortality and catch.

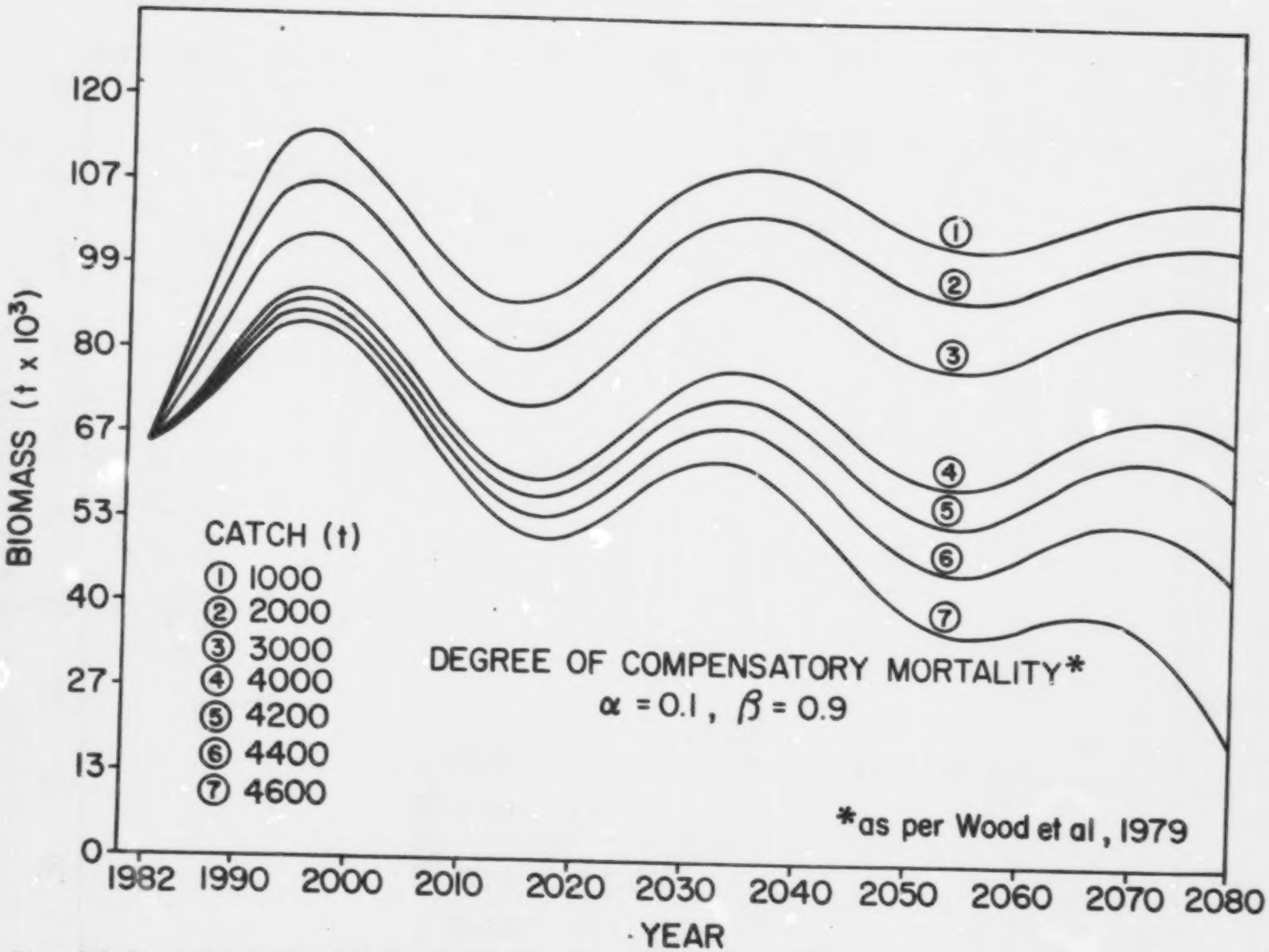


Fig. 7.2.3. Forward simulations of spiny dogfish abundance in the Strait of Georgia-Puget Sound, at varying levels of sustained yield.

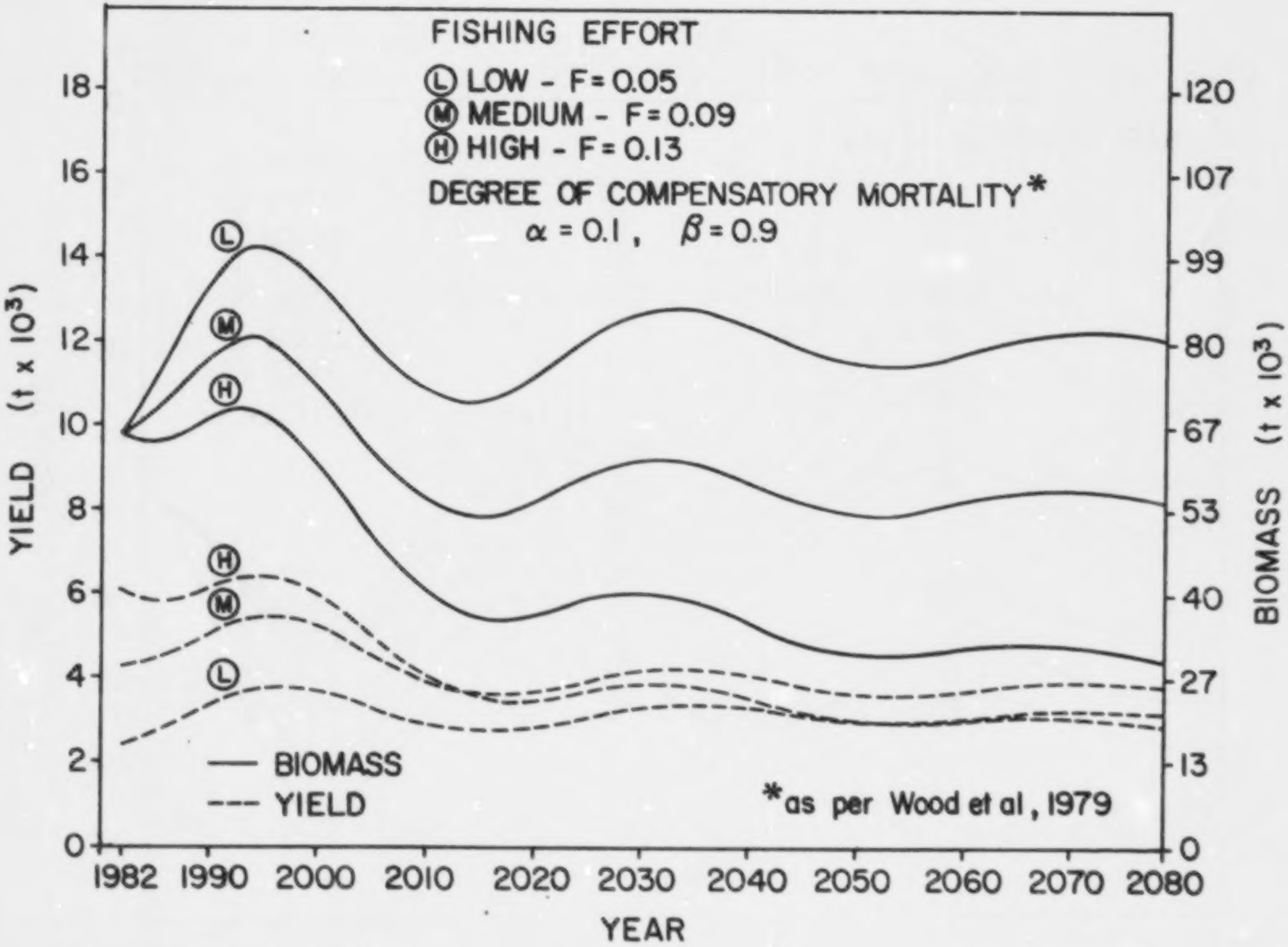


Fig. 7.2.4. Forward simulations of spiny dogfish yield and abundance in the Strait of Georgia-Puget Sound, at varying levels of sustained effort.

Table 7.1.1. Dogfish landings[a] (t) offshore, excluding dumped and discarded fish by Major Area and by gear for 1979-1984.

	3C			3D			5A			5B			5C			5D			5E			Total		
	LL	Tr	Tot.	LL[b]	Tr[c]	Tot.	LL	Tr	Tot.	LL	Tr	Tot	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot.
1979	4	279	283	1	15	16	5	10	15	-	5	5	1	11	12	26	70	96	-	-	-	33	390	423
1980	7	1732	1739	17	116	133	5	117	122	-	39	39	13	59	72	91	242	333	-	1	1	133	2306	2439
1981	10	285	295	-	17	17	-	25	25	-	-	-	-	9	9	10	32	42	-	-	-	20	368	388
1982	-	947	447	3	23	26	11	14	25	-	45	45	3	-	3	-	272	272	-	-	-	17	1301	1318
1983	77	451	528	-	54	54	16	-	16	-	9	9	-	3	3	-	17	17	-	-	-	93	534	627
1984[d]	-	319	319	-	-	-	50	9	59	-	23	23	-	15	15	-	24	24	-	-	-	50	390	440

[a] Interview and sales slip data from Smith 1980, 1981, Leaman 1982, 1983.

[b] Longline

[c] Trawl

[d] Cut-off Aug. 10, 1984.

Table 7.1.2. Dogfish landings[a] (t) excluding dumped and discarded fish, for Major Areas 4B and 3C, by gear and by quarter for 1979 to 1984.

	Area 4B											Area 3C				
	Longline					Trawl						Trawl				
	Quarter					Quarter						Quarter				
	I	II	III	IV	Total	I	II	III	IV	Total	Total	I	II	III	IV	Total
1979	747	206	419	2081	3453	9	7	106	669	881	4334	2	200	49	28	279
1980	806	482	23	229	1540	288	34	-	242	564	2104	512	1111	109	-	1732
1981	5	2	-	486	493	88	-	-	182	270	763	37	208	17	24	286
1982	302	67	6	464	839	100	28	120	171	419	1258	209	612	82	44	947
1983	273	128	55	336	792	81	111	70	173	435	1227	180	147	50	73	450
1984[b]	88	-	-	-	88	23	68	-	-	91	179	191	126	11	-	328

[a] Includes sales slip information.

[b] Cut-off Aug. 10, 1984.

8. Walleye pollock

by W. Shaw, G. A. McFarlane and M. W. Saunders

8.0.1. General introduction

Walleye pollock, (Theragra chalcogramma) is a true cod (Gadidae) found throughout British Columbia waters. A typical gadid, pollock are short lived, grow very rapidly and are subject to large fluctuations in recruitment.

Stocks of pollock are present in the Strait of Georgia, off the west coast of Vancouver Island and in Hecate Strait - Dixon Entrance. They have been harvested by mid-water and bottom trawl fisheries for fillets and roe.

8.1. Coastwide

Yield options are not proposed on a coastwide basis.

8.2. Strait of Georgia

8.2.1. Introduction

The walleye pollock fishery in the Strait of Georgia began in the early 1950s as a bottom trawl fishery concentrating in the Gulf Islands area. The landed pollock were used primarily to supply food for farm culture of fur-bearing animals such as mink. Pollock fishing for human consumption began in 1955 but remained small. By 1975 larger markets were established and midwater concentrations were exploited for the first time in the open Strait. The total landings increased sharply in 1978, and peaked in 1979 primarily due to the increased demand for pollock roe by the Japanese markets, and secondly for the pollock fillets. After this the landings decreased annually and to date remain small.

8.2.2. Landings

Walleye pollock landings in the Strait of Georgia peaked in 1979 at 1340 t, and declined to 25 t in 1983 (Table 8.2.1.). Most (92%) of the landings have occurred during the first quarter of each year since the inception of the pollock roe fishery in 1978 (Fig. 8.2.1.). These landings were predominantly from midwater trawlers. First quarter landings from the northern and central Strait of Georgia have declined from a high of 1062 t in 1979 to 11 t in 1983. Similarly, first quarter landings from the Gulf Islands and Juan de Fuca Strait dropped from 236 t in 1979 to 4 t in 1983 (Table 8.2.2.). First quarter landings from Minor Area 18 east of Mayne Island dropped to 9 t in 1983 from the 1980 high of 453 t.

8.2.3. Stock assessment

Biomass estimates

During 1981, three independent methods (trawl swept volume, hydroacoustic, and ichthyoplankton surveys) were conducted to estimate the biomass of spawning pollock in the Strait of Georgia. The trawl swept volume surveys produced a total biomass estimate of 22,600 t ± 6780 t of pollock (Thompson and McFarlane 1982) in the Strait of Georgia. Individual estimates were computed for two areas: central Strait of Georgia to Point Roberts (14,300 t); and Point Roberts to Active Pass (8,300 t).

The biomass estimated by the hydroacoustic survey ranged from 15,000-26,000 t (Kieser 1983). No estimate is available for the ichthyoplankton survey.

Stock delineation

It is believed that the pollock fishery is operating on two different components of one stock in the Strait of Georgia: one in the north and central Strait (Minor Areas 13, 14, 15, 16, 17E, and 29); and the other near east Mayne Island (Minor Area 18E). The size composition data from 1980-1983 indicate that larger female pollock are more abundant in Minor Area 18E than in Minor Areas 14, 16, 17E and 29 (Fig. 8.2.2. and 8.2.3. respectively). This is supported by age compositions for 1983 which indicate that the older pollock were found only in Minor Area 18E (Fig. 8.2.4). Over the last four years little change in length frequencies is evident, suggesting relative stability in the stock (Fig. 8.2.2, 8.2.3).

Estimation of yield

In the absence of an adequate catch and effort data time series necessary for the use of generalized stock production models, previous estimates of maximum sustainable yield (MSY) (Westrheim 1980; Stocker 1981) were calculated using Gulland's (1970) relationship of MSY = a (M)(B_0). Calculated MSY was multiplied by .75, an arbitary figure reflecting uncertainty regarding the models inability to cope with fluctuations in recruitment and the biological response of the stock to recent increases in fishing presssure (Westrheim 1980). In the calculation the value of instantaneous mortality (F) used was 0.6 and the unexploited biomass (B_0) was 15,000 t taken from hydroacoustic surveys (Kieser 1983).

The present assessment uses the same model with biomass estimates taken from trawl swept volume surveys (Thompson and McFarlane 1982). B_0 is between 15,800 t and 29,000 t based on the 95% confidence limits around the survey estimate of 22,600 t. Recent studies (Gulland 1983 a,b) suggest that the true value of a, previously assumed to be 0.5, lies at 0.3 or 0.4. Estimates of instantaneous natural mortality values range from 0.5 to 0.7 (Thompson 1981). Hence, using minimum and maximum levels of a, M and B_0 the MSY ranges between 2350 t and 10,500 t respectively (Fig. 8.2.5).

8.2.4. Recommendations

Yield options range from a conservative 2350 t to a high risk 10,500 t. Based on our understanding of the biology of pollock (a=.4; m=0.5-0.6) and a mid-point in the biomass estimate (22,600 t) we recommend that a yield option be chosen between 2500 t and 5400 t.

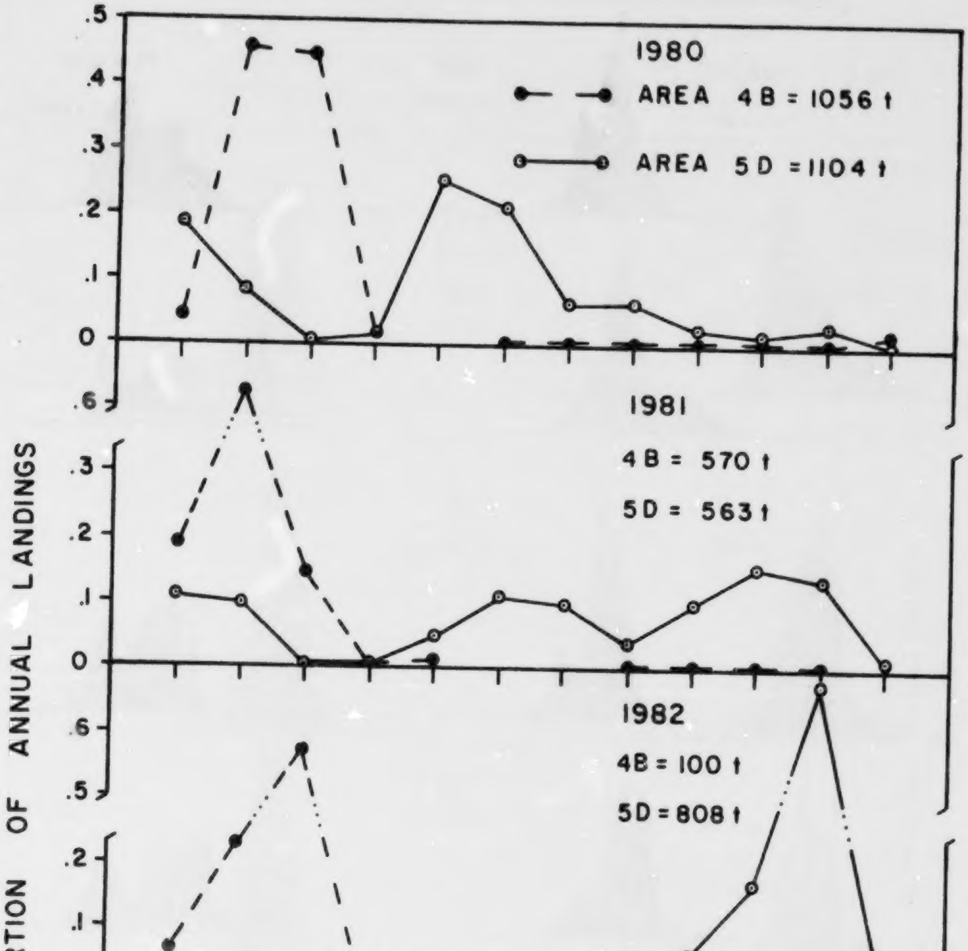


Fig. 8.2.1. Monthly proportions of annual landings for walleye pollock from Major Areas 4B and 5D, 1980-1983.

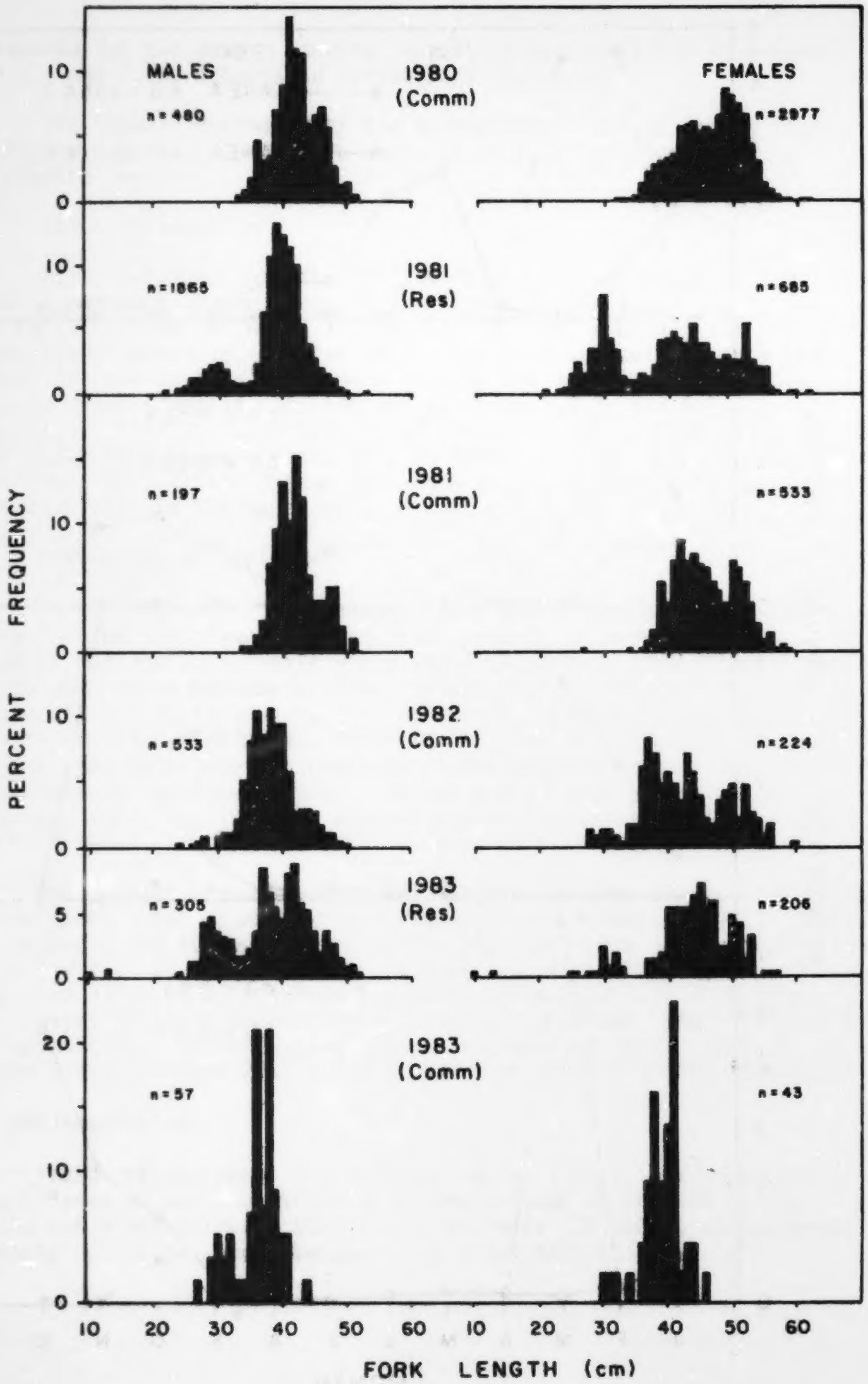


Fig. 8.2.2. Walleye pollock length frequency by set from research and commercial catches from Minor Area 18E (combined gears), 1980-1983.

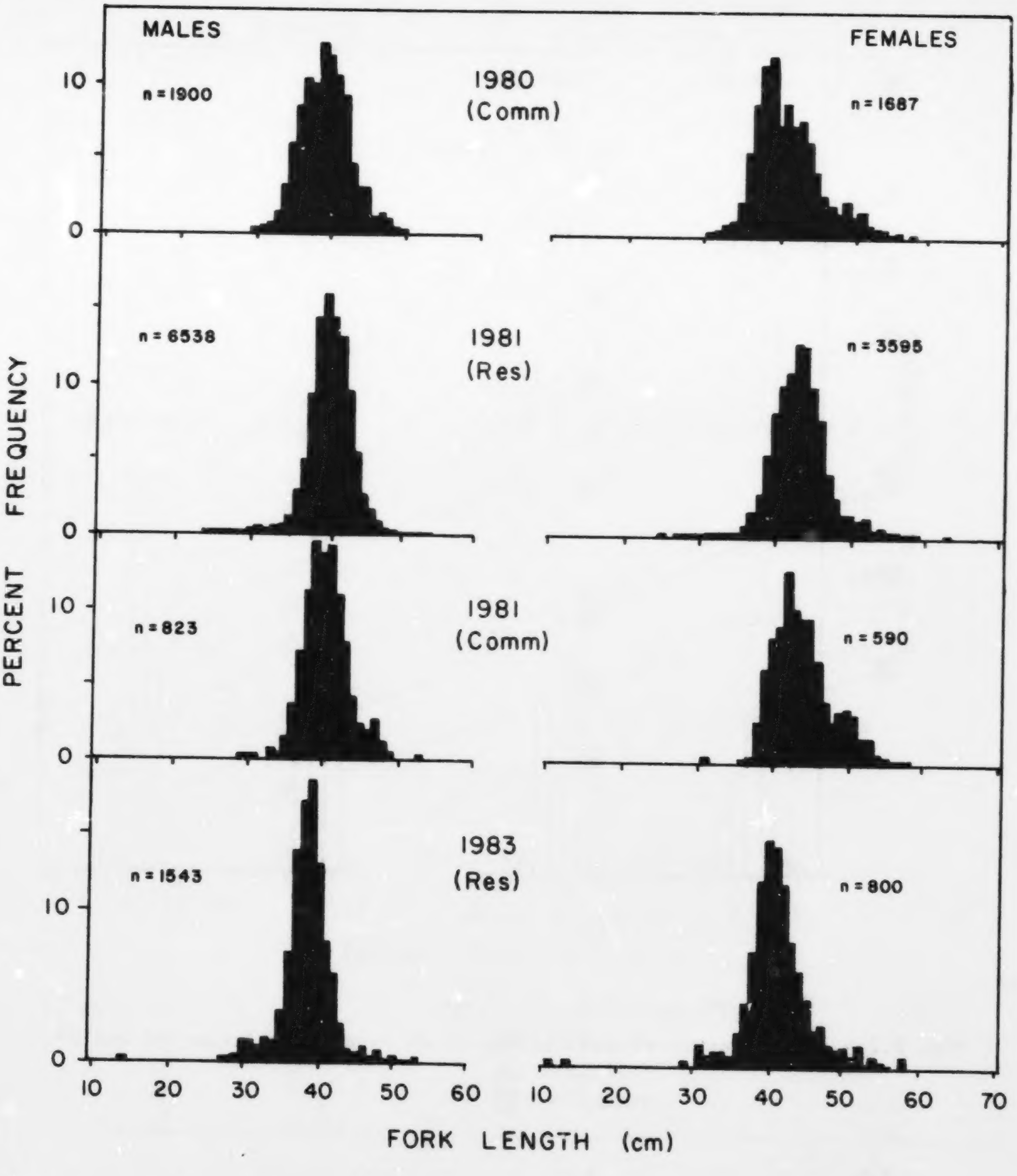


Fig. 8.2.3. Walleye pollock length frequency by sex from research and commercial catches in the Strait of Georgia (excluding Minor Area 18E). All trawl gear combined, 1980-1983.

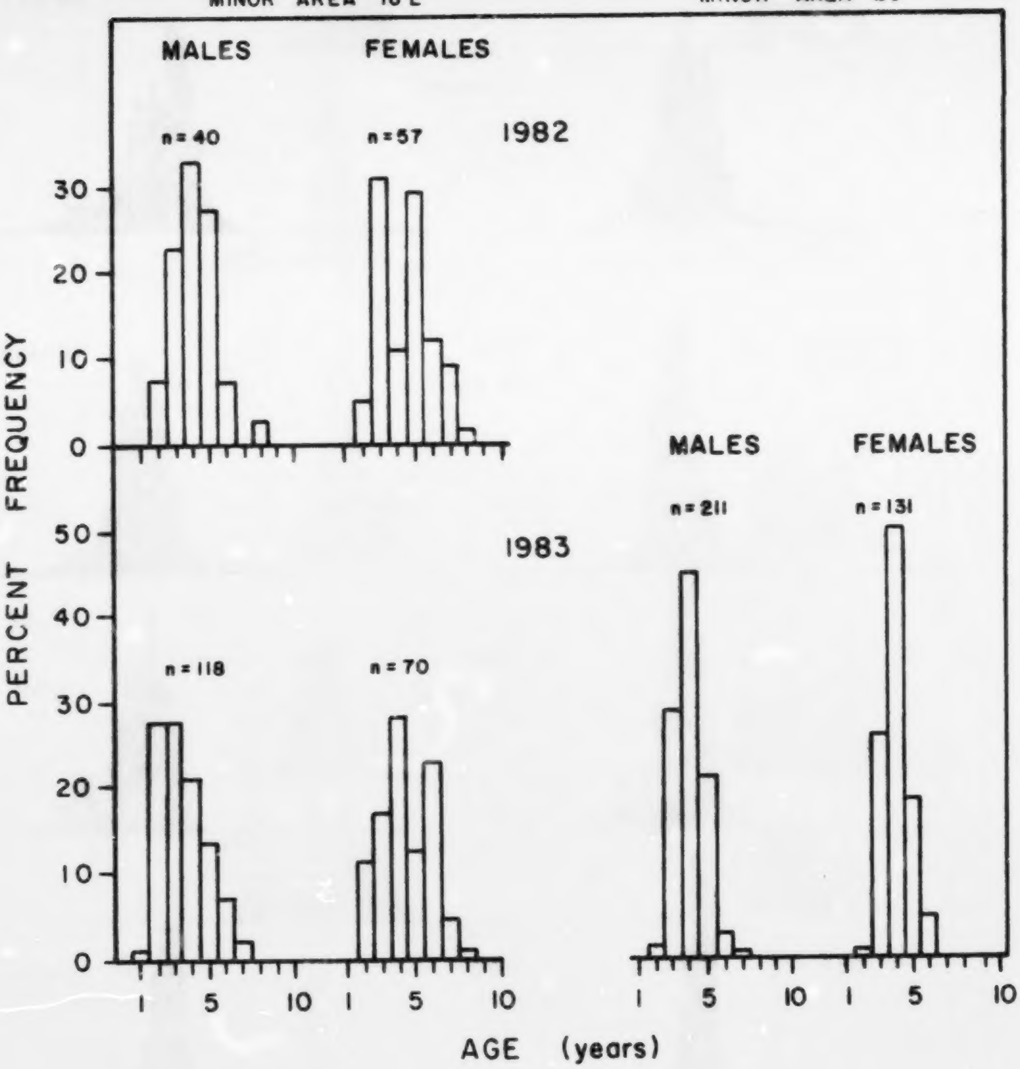


Fig. 8.2.4. Age frequency of walleye pollock from Minor Areas 18E and 29.

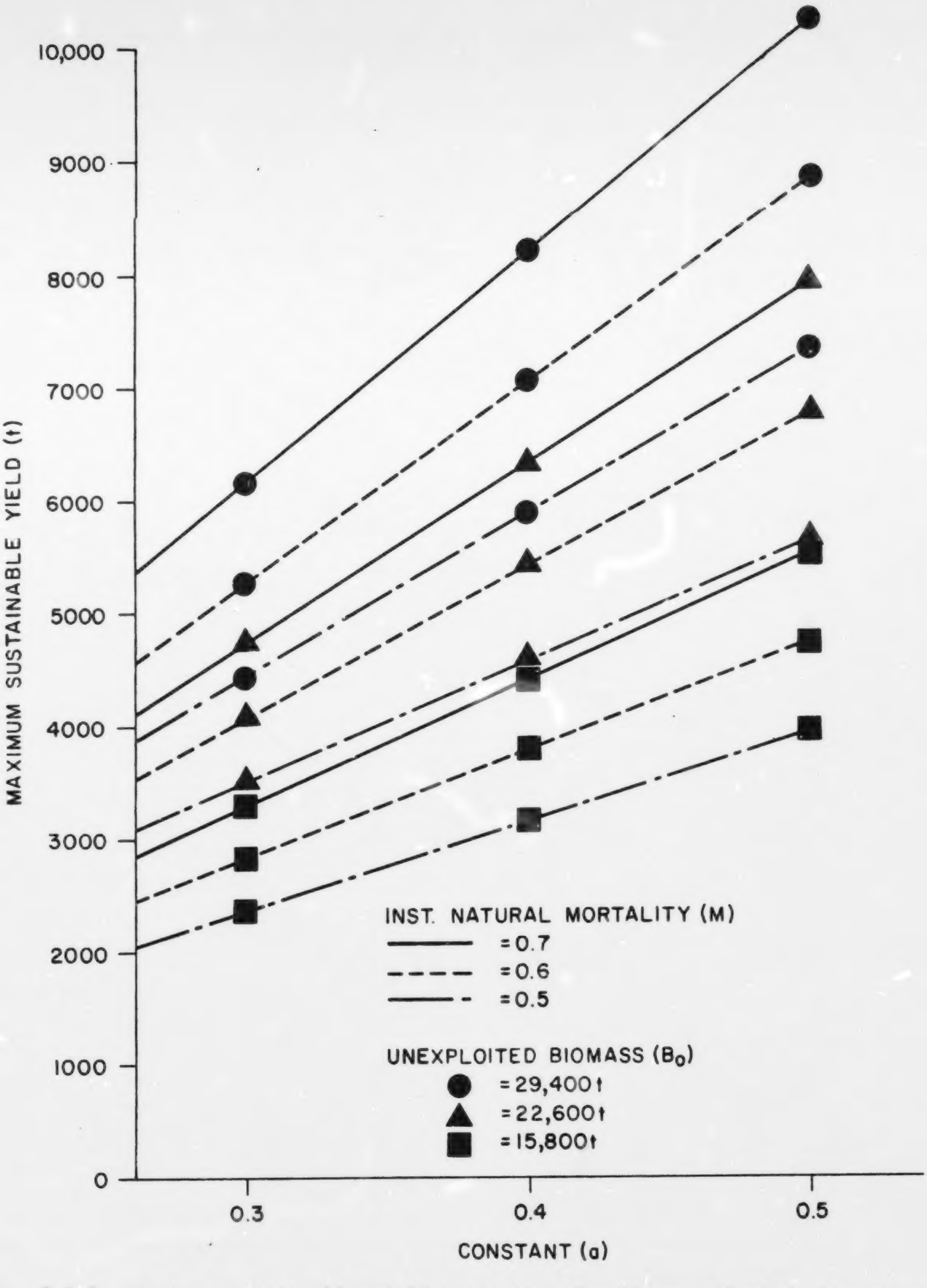


Fig. 8.2.5. Maximum sustainable yield estimates of walleye pollock in the Strait of Georgia at varying levels of a, M and B_o using MSY = aMB_o (Gulland 1979).

Table 8.2.1. Walleye pollock landings by gear type and by quarter from the Strait of Georgia (Major Area 4B), 1976-1983.

	Major Area 4B			
Year	Q_1	Q_2-Q_3	Q_4	Total
1976				
MWT[1]	-	-	-	0
BT[2]	3	<1	23	26
Total	3	<1	23	26
1977				
MWT	-	-	-	0
BT	24	1	26	51
Total	24	1	26	51
1978				
MWT	177	-	-	177
BT	142	20	41	203
Total	319	20	41	380
1979				
MWT	1033	-	3	1036
BT	283	1	20	304
Total	1316	1	23	1340
1980				
MWT	841	-	-	841
BT	189	3	23	215
Total	1030	3	23	1056
1981				
MWT	455	10	-	465
BT	99	1	5	105
Total	554	11	5	570
1982				
MWT	81	<1	-	81
BT	8	4	7	19
Total	89	4	7	100
1983				
MWT[1]	19	-	-	19
BT[2]	3	1	2	6
Total	22	1	2	25

[1] MWT = Midwater trawl.

[2] BT = Bottom trawl.

Table 8.2.2. Walleye pollock landings by year type and by Minor Area for the first quarter from the Strait of Georgia, 1978-1983.

	Minor Area			
Year	13,14,15,16,17E,29 (N and C Georgia St.)	18E (E. Mayne Is.)	17W, 18W 19, 20 (Gulf Is. & J. de Fuca)	Total
1978				
MWT[1]	177	-	-	177
BT[2]	-	-	142	142
Total	177	-	142	319
1979				
MWT	924	1	108	1033
BT	138	17	128	283
Total	1062	18	236	1316
1980				
MWT	504	322	14	841
BT	<1	131	59	189
Total	504	453	73	1030
1981				
MWT	451	4	<1	455
BT	26	59	14	95
Total	477	63	14	554
1982				
MWT	20	56	5	81
BT	-	-	8	8
Total	20	56	13	89
1983				
MWT	11	8	<1	19
BT	-	1	2	5
Total	11	9	2	24

[1] MWT = Midwater trawl.
[2] BT = Bottom trawl.

8.3. West Coast Vancouver Island

8.3.1. Introduction

Walleye pollock have remained an incidental catch mainly in the joint venture Pacific hake fishery off the west coast of Vancouver Island (Major Area 3C). Since 1980, the incidental catch of pollock has been estimated by observers on board the foreign processing vessels. The average annual incidental catch was 891 t with a high of 1687 t caught in 1980 and a low of 19 t caught in 1983 (Table 8.3.1).

The domestic fishery occurs in Areas 3C and 3D. Annual landings from both areas 3C and 3D have remained very small, averaging 7 t for the period 1954-1983.

8.3.2. Biological data

Biological data for walleye pollock off the west coast of Vancouver Island are limited. Length frequencies collected from both research and commercial vessels are presented in Fig. 8.3.1 for the period 1976-1983. It appears that the size composition of the stock has remained relatively constant. Age frequencies indicate that 3 yr-olds dominated the 1976 and 1983 catches (Fig. 8.3.2).

8.3.3. Recommendations

An unlimited yield option is proposed for this region. Accurate estimates of incidental catch and biomass are unavailable. In addition, the extent of interchange between this stock(s) and pollock in the Strait of Georgia is currently being investigated. When these studies are completed, coupled with the accumulation of more accurate catch/effort statistics from Areas 3C and 3D, the stock will be re-evaluated.

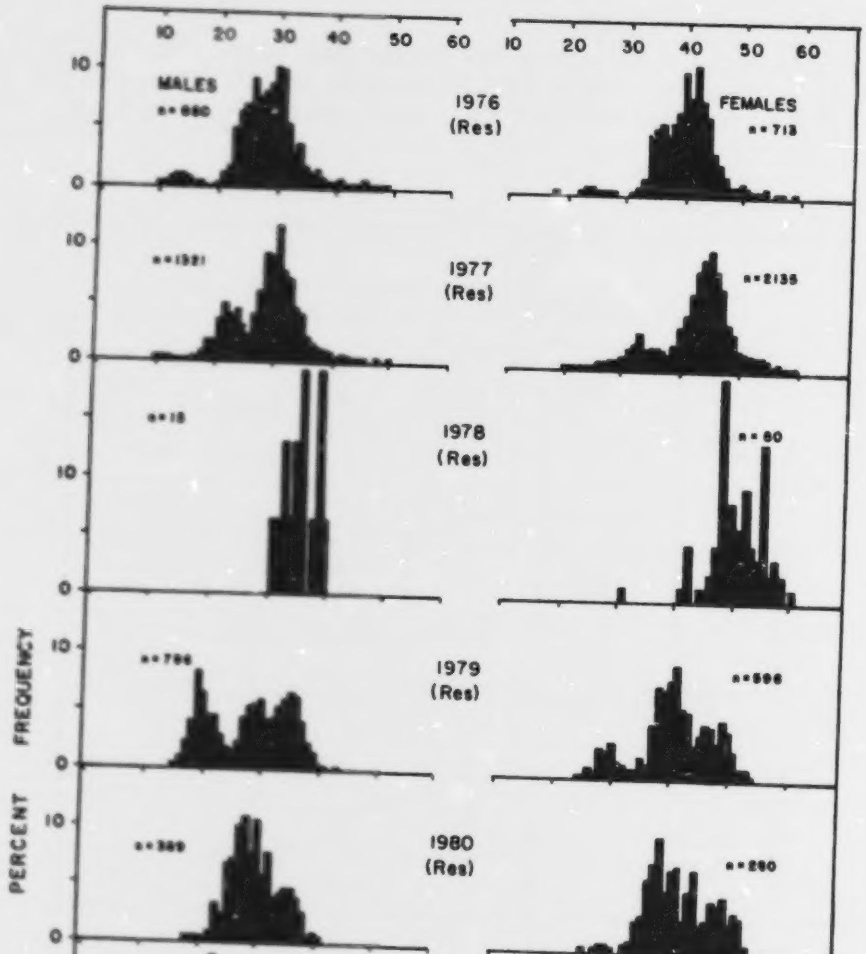


Fig. 8.3.1. Walleye pollock length frequency by sex from research and commercial catches from Major Area 3C, 1976-1983.

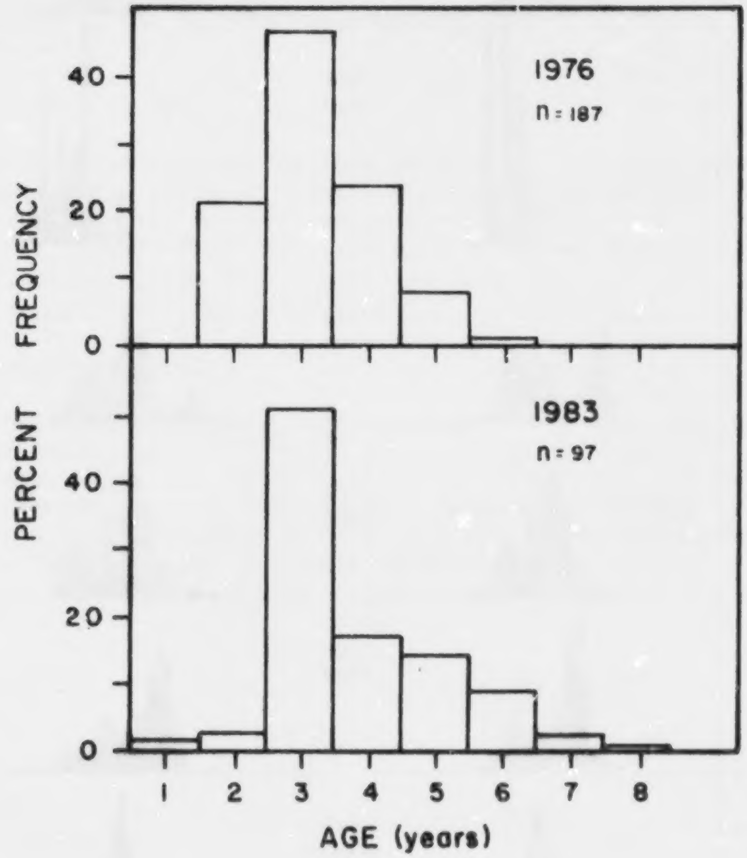


Fig. 8.3.2. Age frequency of walleye pollock from Major Area 3C, 1976 and 1983.

Table 8.3.1. Incidental catches of walleye pollock by foreign and domestic fleet participating in the offshore hake fishery off west coast Vancouver Island (Major Area 3C), 1980-1983. (Catch statistics from Offshore Division, Vancouver.)

		Landings (t)			
Year	Nations	National[a]	Joint venture	Domestic	Total
1980	Poland	487	236		
	USSR	63	584		
	Japan	142	0		
	Greece	-	175		
	Total	692	995	3	1690
1981	Poland	131	205		
	USSR	26	299		
	Japan	9	0		
	Greece	-	285		
	Total	166	789	9	964
1982	Poland	468	222		
	USSR	0	149		
	Japan	38	-		
	Total	506	371	10	887
1983	Poland	13	6		
	USSR	-	-		
	Total	13	6	3	22

[a] "National" landings include landings from the supplementary fishery.

8.4. Queen Charlotte Sound

Yield options are not proposed for this region.

8.5. Hecate Strait

8.5.1. Introduction

The walleye pollock fishery in northern Hecate Strait and Dixon Entrance (Major Area 5D) expanded in 1976 when the demand for fillets from larger adults as food fish increased. There was a further increase in 1978 as a result of a developing roe fishery aimed primarily at supplying the Japanese market.

Pollock in Dixon Entrance appear to be part of a larger stock found off S.E. Alaska (Thompson 1981). These observations are supported by information on differences in parasite incidence and proportions in pollock musculature (Arthur 1983).

8.5.2. Landings

Walleye pollock landings peaked in 1978 at 1700 t in Major Area 5D then decreased to 563 t in 1981 (Table 8.5.1). Most (67%) of these landings were made by bottom trawlers during the second and third quarters (Table 8.5.2). Bottom trawl landings decreased to 98 and 81 t in 1982 and 1983, respectively, during the second and third quarters. Landings during the first quarter roe fishery peaked in 1979 at 712 t, then fell to 132 t in 1981 and 44 t in 1983.

The small landings in 1981 are a result of the failure of the roe fishery which was largely attributed to the decline in average size, high incidence of immature pollock, and decline in abundance of adults (Stocker 1981). During 1982 and 1983 total landings increased to 808 and 944 t, respectively. The majority (75%) of the catches during these years were landed in the fourth quarter by midwater trawlers. This increased production during the fall months was due to an increased demand for pollock fillets at this time of year (Table 8.5.2; Fig. 8.2.1, Area 4B).

Landings in Major Area 5C peaked in 1979 at 238 t and decreased to 6 t in 1983 (Table 8.5.2).

8.5.3. Stock assessment

Size composition of the landings has remained relatively constant since 1981 (Fig. 8.5.1). Age frequencies of the 1982 and 1983 catches indicate that the 1977 year-class predominated (Fig. 8.5.2). It appears that the 1978 year-class as 5-yr-olds in 1983 is also relatively strong.

Yield per recruit analysis for pollock in Major Area 5D utilized the following parameters: $K = 0.45$, $t_0 = 0.1$, $b = 3.0$, $W = 1838$ gm, and $M = 0.45$ to derive the Beverton Holt yield per recruit isopleth diagram (Fig. 8.5.3). Yield per recruit increases slowly over a range of fishing mortality of 0.15-1.0 as the age of first fished increases from 4-6 years.

Yield per recruit analysis suggests optimum yield between ages 5 and 6. The age composition data for 1983 and preliminary results for 1984 indicate that 5-6 and 5-7 yr-old pollock, respectively, dominate the catches.

8.5.4. Recommendations

An unlimited yield option is proposed for this region. The stock is currently underexploited due to intermittent availability and weak market demand.

8.6. West Coast of Queen Charlotte Islands

Yield options are not proposed for this region.

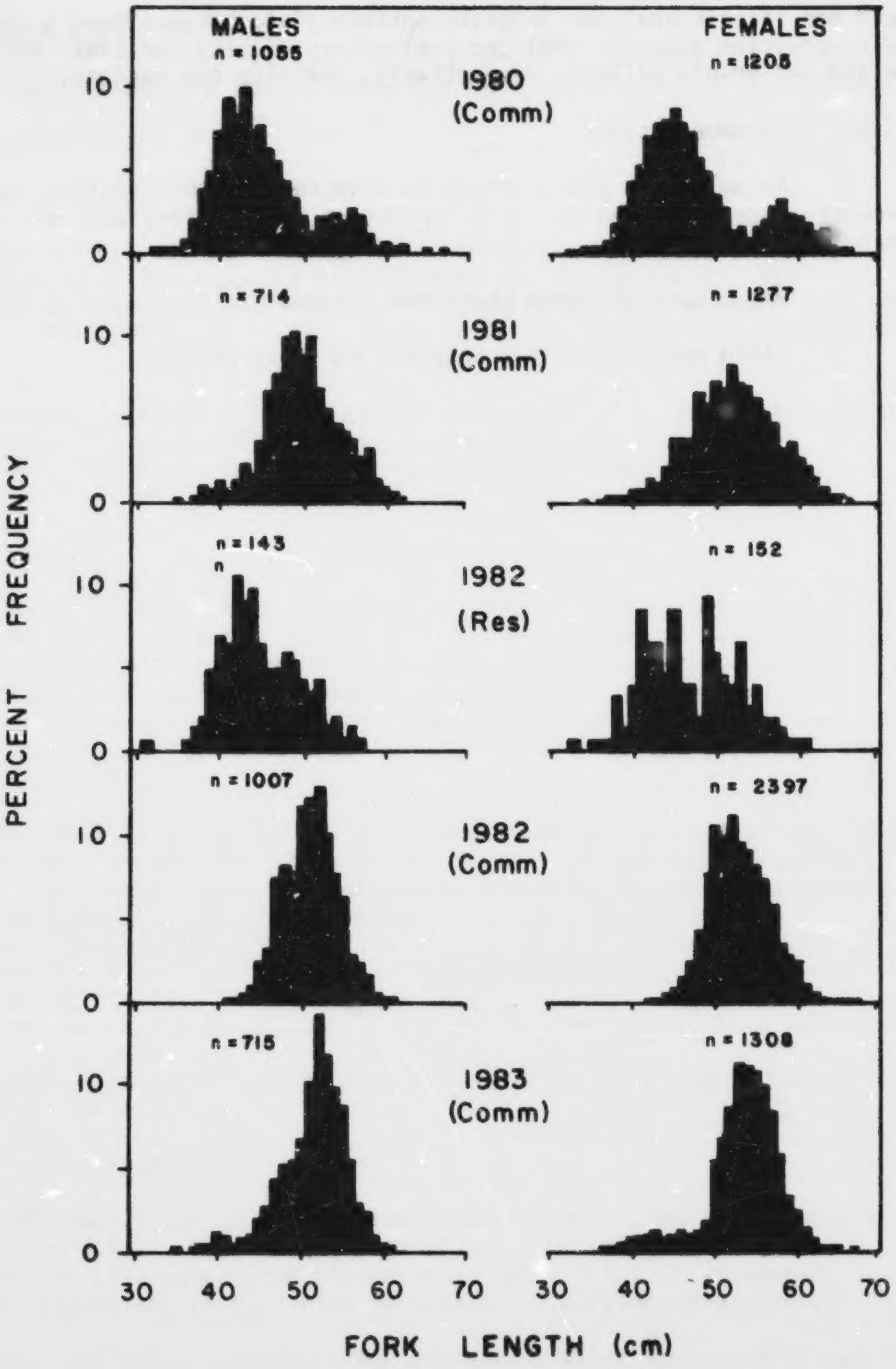


Fig. 8.5.1. Walleye pollock length frequency by sex and by research and commercial catches from Major Area 5D (combined years), 1980-1983.

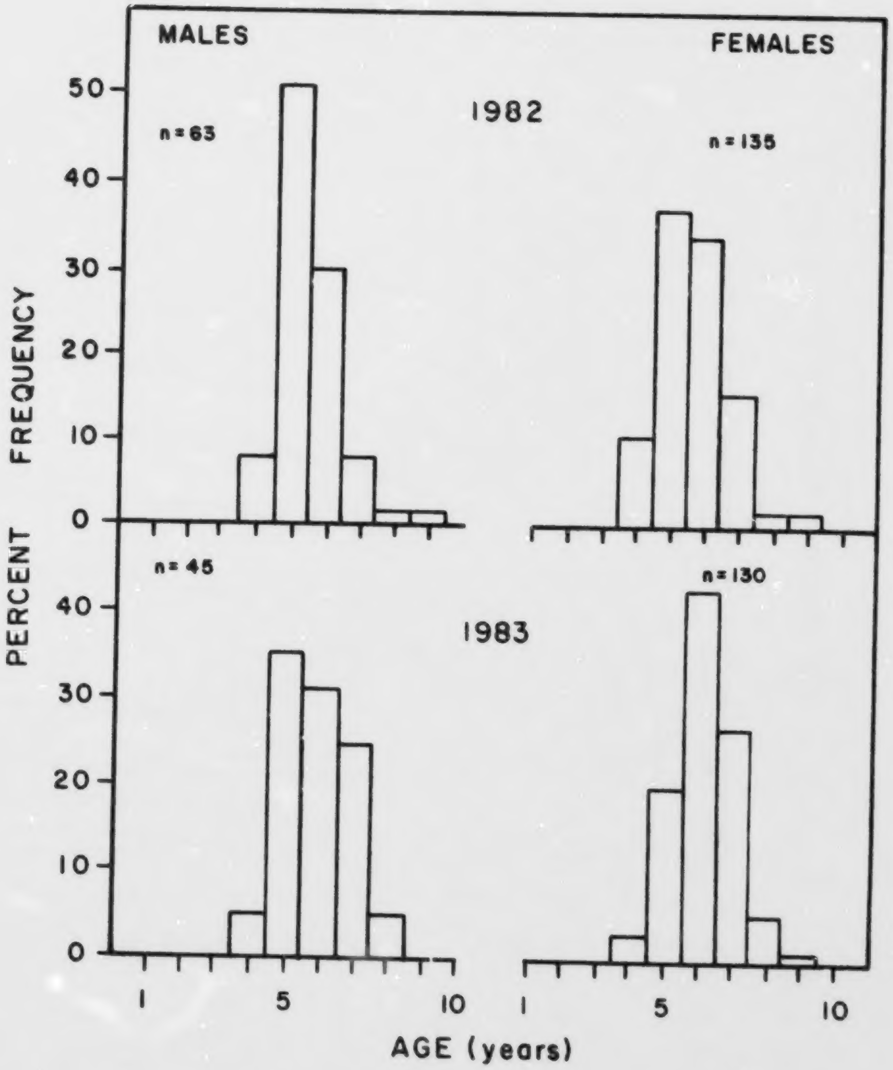


Fig. 8.5.2. Age frequency of walleye pollock from Major Area 5D, 1982-1983.

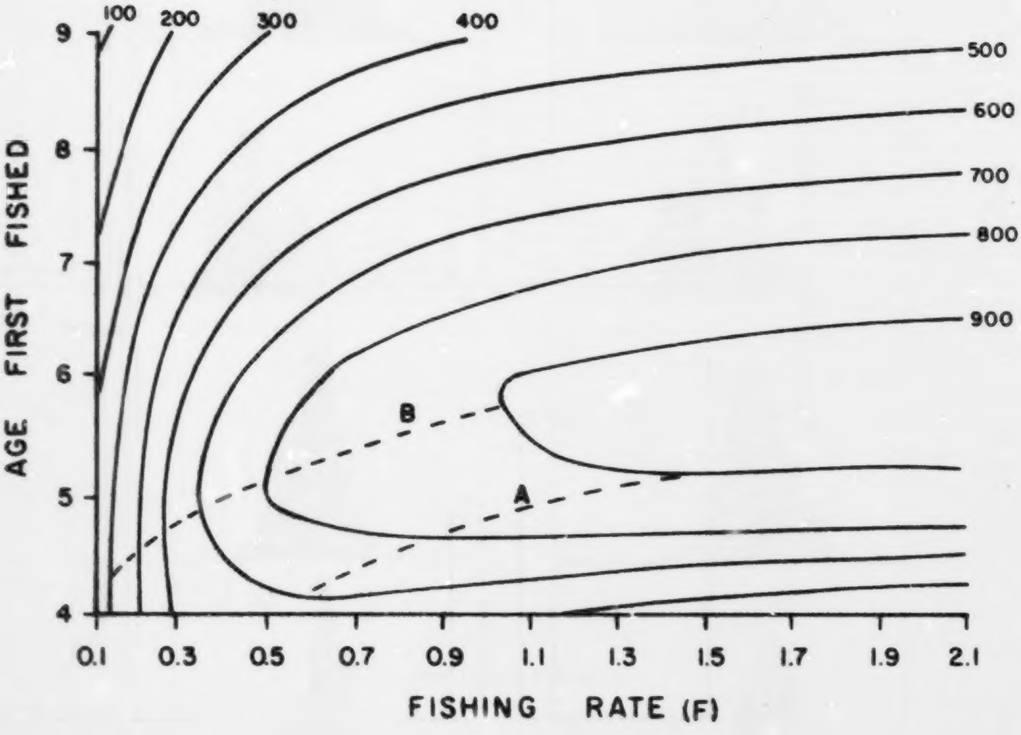


Fig. 8.5.3. Yield per recruit isopleths for walleye pollock from Major Area 5D. Line A gives F with the best yield for given ages at recruitment. Line B gives the age of recruitment with best yield at given levels of F.

Table 8.5.1. Total landings (t) of walleye pollock by the domestic fleet by Major Statistical Area, 1954-83.

Year	Landings (t)									
	4B	3B	3C[1]	3D	5A	5B	5C	5D	5E	Total
1954	147	0	3	0	13	1	0	0	0	164
1955	418	0	5	0	1	0	0	3	0	426
1956	380	0	52	0	5	0	0	14	0	451
1957	248	0	4	0	3	0	0	7	0	262
1958	121	0	0	0	0.3	0	0	14	0	145
1959	260	0	8	0	0.4	0	0	2	0	270
1960	95	0	5	0	1	3	0	10	0	114
1961	115	0	0.1	0	1	0	0.3	7	0	123
1962	49	0	6	0	0	0	0	12	0	67
1963	13	0	7	0	6	0	0	4	0	29
1964	33	0	2	0	5	0	0	2	0	42
1965	26	0	10	0	0	0	0	9	0	45
1966	37	0	0.4	0	1	0.1	0.4	82	0	121
1967	33	1	0	0	1	0	7	48	0	90
1968	16	0	2	0	7	0	4	13	0	42
1969	30	0	14	0	33	0	0	47	0	125
1970	45	0	0	0	0	0	0	8	0	52
1971	80	0	5	0	0	0	0	0	0	85
1972	71	0	0.3	0	172	0	0	1	0	244
1973	9	0	0.1	0	62	9	0.4	13	0	93
1974	11	0	0	0	6	6	2	47	0	72
1975	1	0	0	0	21	10	1	70	0	104
1976	26	0	5	2	69	400	193	627	0.2	1,322
1977	50	0	10	0	61	175	16	568	12	891
1978	380	0	6	0.4	106	187	11	1,700	21	2,411
1979	1,341	0	31	0.3	72	71	238	1,566	67	3,385
1980	1,056	0	3	3	12	23	83	1,104	18	2,303
1981	570	0	8	1	2	10	80	563	22	1,255
1982	100	0	10	0	1	6	3	808	1	974
1983	25	0	3	1	11	10	6	944	28	1,029

[1] Excludes incidental landings by the foreign fleet participating in the offshore Pacific hake fishery during 1980 to 1983.

Table 8.5.2. Walleye pollock landings by gear type and by quarter from Major Areas 5C and 5D, 1976-1983.

	Major Area 5C				Major Area 5D			
Year	Q_1	Q_2-Q_3	Q_4	Total	Q_1	Q_2-Q_3	Q_4	Total
1976								
MWT[a]	-	25	102	127	-	208	56	264
BT[b]	<1	19	47	66	5	141	214	360
Total	<1	44	149	193	6	349	270	625
1977								
MWT	-	-	-	0	<1	<1	-	<1
BT	1	14	1	16	34	509	24	567
Total	1	14	1	16	34	509	24	567
1978								
MWT	-	1	-	1	425	299	71	795
BT	1	7	2	10	107	657	141	905
Total	1	8	2	11	532	956	212	1700
1979								
MWT	-	-	-	0	593	52	11	656
BT	1	103	134	238	119	521	270	910
Total	1	103	134	238	712	573	281	1,566
1980								
MWT	-	<1	-	<1	201	261	9	471
BT	1	73	9	83	116	482	34	632
Total	1	73	9	83	317	743	43	1,103
1981								
MWT	-	-	-	0	61	-	79	140
BT	27	21	31	79	71	248	104	424
Total	27	21	31	79	132	248	183	563
1982								
MWT	-	-	-	0	2	-	607	609
BT	<1	3	<1	3	4	98	97	199
Total	<1	3	<1	3	6	98	704	808
1983								
MWT	-	-	-	0	-	-	704	704
BT	-	6	-	6	44	81	115	240
Total	0	6	0	6	44	81	819	944

[a] MWT = Midwater trawl.
[b] BT = Bottom trawl.

9. SHELF AND SLOPE ROCKFISHES--B. M. Leaman and R. D. Stanley

9.0. Introduction

Yield options

To assist in the formulation of a framework for management of rockfish stocks, it is appropriate to review the spectrum of available options. We conceive of five options for harvesting stocks: (i) zero harvest; (ii) conservative harvest; (iii) sustainable harvest; (iv) non-sustainable harvest; and (v) unrestricted harvest.

(i) Zero harvest

This option could be entertained under situations of known and severe stock depletion, or where particular areas may represent necessary refuges for the fish. Additional ecological considerations might include situations where the subject stock acts as a predator on a less desirable species, and the objective is to maximize predation.

(ii) Conservative harvest

Under this option, the probability of overfishing is minimized while the probability of rehabilitation for depleted stocks is increased. With the exception of option (i), this approach will incur the lowest risk of deleterious effects on stock biomass and dynamics. However, it is also true that some yield from the stock will be lost to the fishery in this process and the manager must be aware of this.

(iii) Sustainable harvest

This option provides some opportunity to maintain stocks at existing levels. In many ways this is the least certain of the options available since it entrains many assumptions about the behaviour of stocks in response to fishing and biological processes. This option should be taken to mean that the probabilities of either decline or increase in yield (biomass) are approximately equal. The term "sustainable" should be understood in its broad sense, i.e. that the stock will oscillate around the expected level as a result of oscillation in recruitment, rather than be maintained at a fixed level. The amplitude and frequency of these oscillations may vary considerably among and within stocks at different levels of biomass. In the simplest terms, this is our best estimate of the highest yield at existing stock levels.

(iv) Non-sustainable harvest

Employment of this option would imply either experimental or non-biological management, since stock declines are highly probable with such a policy in effect over a significant portion of the average life of a population cohort. Instances where this option might be considered include: economic or social conditions requiring short-term yields which are higher than those that could be sustained over longer periods; experiments where the effects of well defined and disparate exploitation rates need to be known; when particularly strong cohorts enter the fishery and can withstand higher exploitation; or, when attendant management policies may require pulsed fishing pressure on a number of different stocks.

Concomitant with the use of this option is the requirement that management will have to shift to a conservative policy to offset the deleterious effects prior to major and irreversible changes in the target stock. In this sense, the use of this option either guarantees a pulsed exploitation pattern if the stock is to be maintained at the most productive level, or accepts short-term gains over long-term productivity.

The hazard associated with this option will vary with the biological characters of the target stocks. In particular, the residence time of a cohort in the vulnerable stock will be a key determinant in the detection and response time associated with the option. Where residency is long, higher than sustainable yields may be maintained over several years in spite of strongly deleterious, yet undetected, effects on subsequent cohorts. Conversely, a short residency may permit more rapid detection of adverse effects although incremental increases in quotas should be small if uncertainty about effects is high.

(v) Unlimited harvest

A very limited number of conditions would call for consideration of this option. Depletion of stocks and elimination of fisheries when harvests are uncontrolled are well documented throughout the world. However, this option might be considered: for experimental purposes; for stock eradication (in the case of competing species); or for economic returns where the loss of a particular stock does not outweigh the chaotic effects that lowered yield would create in the industry. A final situation where this option might be considered is where there is little or no information available on the target stock. In such instances, a more restrictive short-term policy may not be warranted and this option could be used to obtain baseline information for analysis and management.

In the case of several rockfish stocks, the yield options identified are based on limited and/or poor quality information, and thus are not supported by detailed scientific analyses. Were rockfish stocks to have shown more resilience to exploitation we would, with the same data bases, be inclined to be more liberal in our identification of yield options, even at times to identify unrestricted harvest as an option so as to gather more baseline data. However we do not follow such a policy for rockfishes, since the exploitation histories of species such as Pacific ocean perch and widow rockfish argue forcefully that rockfish management should be highly conservative. This viewpoint contributes to the identification of yield options even for stocks where little fishing has occurred. In such cases a ceiling or threshold level of yield is identified which would, should a significant fishery suddenly develop, prevent a drastic over-harvest. Holding the landings to such a level would permit some opportunity for assessment and orderly development of the fishery.

Management options

Within the general framework outlined above, we are presenting an additional option for management of some rockfish species and stocks. Using cluster analysis and analysis of covariance, rockfish catches have been examined to determine if they can be segregated into assemblages of species that persist over sufficiently long periods to be useful as management units. Results indicate that relatively stable units exist within shelf and slope groups in some areas over the full year, or within segments of the year long enough to be useful for management (Nagtegaal 1983).

The potential value of assemblage management is that it simplifies fishing and enforcement by reducing the number of species quotas that need to be monitored and enforced within given areas. However, it should also be understood that management precision is decreased due to the relatively dynamic composition of assemblages among years. While this is unavoidable, the option is presented because the precision of single-species management is dependent on the ability of fishermen to target on specific stocks and quotas. Assemblages are presented in recognition of this reality. Additionally, asemblages may be suggested where individual yield options are so small as to make enforcement of them impossible.

In some instances, the total for an assemblage unit will be less than the sum of the species contributing to the assemblage. This reflects the variability in the proportional composition of the assemblage and the possibility that a substantial portion of the total might, on occasion, be obtained from only one species of the unit. In these instances, we have suggested a lower unit figure under each option with the provision for review of the composition of the catch at this figure, and increases if the total is distributed among species according to projections. The use of assemblage units ignores the "minor" species and it is the intent that such species would not contribute to quota catches, should this option be chosen. The catches of these species would, of course, have to be monitored, primarily to help us resolve the structure of assemblages for future use.

In the following sections we present management options by yield level [options (ii)-(v)] and by species clusters (single species (A), partial clusters (B), and full clusters (C)). Not all options will be appropriate for all species and areas and this is reflected in the tables. Finally, we add a cautionary note in consideration of a review of the achievement of management objectives that were based on the yield options identified for rockfishes in recent years. In several instances quotas have been divided in areas and the result has been greater total overruns. The extent to which quotas have been exceeded seems to be independent of the quota itself. Thus, if a quota is divided into two areas it appears this leads to twice the overrun for the overall area. Additionally, if within assemblage management the overruns consistently exceed sustainable levels, then we suggest using individual species quotas so that the impacts of over-exploitation can be limited to specific stocks.

Rockfishes have been divided into shelf and slope groups in recognition of the most natural distribution and biological affinities.

9.1. Slope rockfishes (Pacific ocean perch, rougheye rockfish, yellowmouth rockfish)

--by B. M. Leaman

9.1.1. Coastwide. Yield options are not proposed on a coastwide basis.

9.1.2. Strait of Georgia. Yield options are not proposed for this area.

9.1.3. West coast of Vancouver Island--Areas 3C/3D

A. Pacific ocean perch (S. alutus)

The only slope rockfish sufficiently abundant to support a directed fishery off the west coast of Vancouver Island is Pacific ocean perch (S. alutus). Stock boundaries for slope rockfishes in this area are not well understood but available evidence suggests a southern 'stock' extending south of 49°30' to at least the Juan de Fuca canyon (Fig. 1.2.) and a northern 'stock' extending from 49°30' to the 3D northern boundary (50°30'). The northern stock is for the purposes of this report entirely within Area 3D and that area has received little commercial or research attention. This assessment therefore concentrates on the southern stock.

(i) Landing statistics--southern stock

Tables 9.1. and 9.2. detail landing statistics of the foreign and domestic fleets for the southern stock. North American landings peaked in 1962, prior to an intensive Soviet-Japanese fishery which began in 1965. Subsequent to the foreign fishery, domestic landings have never approached peak historical levels, for the stock as a whole. However, landings by Canadian vessels in the Canadian zone have increased since 1979, after a two-year closure to directed fishing. Quota management for this stock has been in effect since 1980. Qualified (25%) LPUE for this fishery from 1980-83 showed a weakly inverse relationship, which we believe is an additional indication of low stock biomass. If stock biomass were larger we would expect greater variations of LPUE with given levels of effort, whereas low LPUE is generally associated with high effort and vice versa.

(ii) Stock assessment

Several analyses of the southern stock (in its broad context of the INPFC Vancouver Area) have been completed. Estimates of virgin biomass range from 53,000 t (Kimura and Tagart 1982) through 62,000 t implied by Gunderson (1981), to a high of 81,000 t inferred from the data in Westrheim et al. (1972). The variance of the estimated virgin stock arises primarily because of different assumptions concerning recruitment, catchability and mortality. Despite the variance there has been general agreement on the decline of the stock during and after the intense fishery of the mid-1960s. Westrheim et al. (1972) and Gunderson (1981) estimated biomass over the 1966-68 period as 34,000 t and 36,411 t, respectively. Using a $\log_e$ (LPUE) fishing power model Kimura (1981) deduced that stock biomass in 1969 had been reduced by 75% from that of 1956, although no absolute estimates were supplied. Subsequently, Kimura and Tagart (1982) reported the 1956 and 1969 biomass levels as 53,000 t and 13,250 t respectively. Gunderson's (1981) cohort analysis estimated mean biomass during 1969-71 as 15,454 t; that of 1972-74 as

Table 9.1. Estimated Pacific ocean perch landings from the INPFC Vancouver area, 1956-1984.

Year	Landings (t)				
	U.S.	Canada	Foreign	JV[a]	Total
1956	1,084	-	-	-	1,084
1957	1,154	-	-	-	1,154
1958	675	-	-	-	675
1959	968	-	-	-	968
1960	1,575	-	-	-	1,575
1961	2,479	6	-	-	2,485
1962	3,854	3	-	-	3,857
1963	3,767	2	-	-	3,769
1964	2,048	47	-	-	2,095
1965	2,961	7	500	-	3,468
1966	2,283	3	14,000	-	16,286
1967	783	7	12,678	-	13,468
1968	526	1	9,865	-	10,392
1969	528	2	2,827	-	3,357
1970	1,170	309	2,368	-	3,847
1971	627	230	2,738	-	3,595
1972	468	118	1,981	-	2,567
1973	308	0	3,479	-	3,787
1974	255	3	1,186	-	1,444
1975	308	6	504	-	818
1976	729	1	521	-	1,251
1977	897	16	T	-	913
1978	958	56	-	-	1,014
1979	616	125	-	-	741
1980	397	430	-	8	835
1981	234	548	5	3	790
1982	309	514	6	1	830
1983	266	837	44	-	1,147
1984[b]	Unk.	352			

[a] Joint-venture.

[b] To July 20.

Table 9.2. Canadian interviewed landings (t), effort (h), and LPUE (t/h) of Pacific ocean perch (Sebastes alutus) from Area 3C.

Area 3C							
		Interviewed					
		0% Qualification			25% Qualification		
Year	Total landings	L	E	LPUE	L	E	LPUE
1967	4.47	4.47	6.5	0.687	4.28	4.5	0.951
1968	0.12	0.12	6.3	0.018	-	-	-
1969	-	-	-	-	-	-	-
1970	298.84	296.77	444.8	0.667	273.11	293.2	0.932
1971	206.99	201.14	552.0	0.364	190.50	333.7	0.571
1972	72.24	13.25	21.3	0.624	12.67	14.3	0.889
1973	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-
1975	5.46	5.46	166.5	0.033	1.46	7.0	0.208
1976	1.29	1.29	5.0	0.257	0.87	1.0	0.869
1977	15.04	13.81	447.5	0.031	8.67	42.3	0.205
1978	48.88	48.57	57.8	0.841	47.51	32.0	1.485
1979	80.62	79.91	147.1	0.543	77.14	44.9	1.718
1980	285.59	284.77	448.2	0.635	277.93	234.9	1.183
1981	381.54	364.99	750.8	0.486	341.61	430.5	0.794
1982	395.23	372.29	740.3	0.503	342.56	430.7	0.795
1983	373.97	179.30	348.3	0.515	167.71	143.3	1.171
1984	111.37	24.25	39.2	0.619	23.72	36.0	0.659

[a] At least 25% of landing must be S. alutus for inclusion of data.

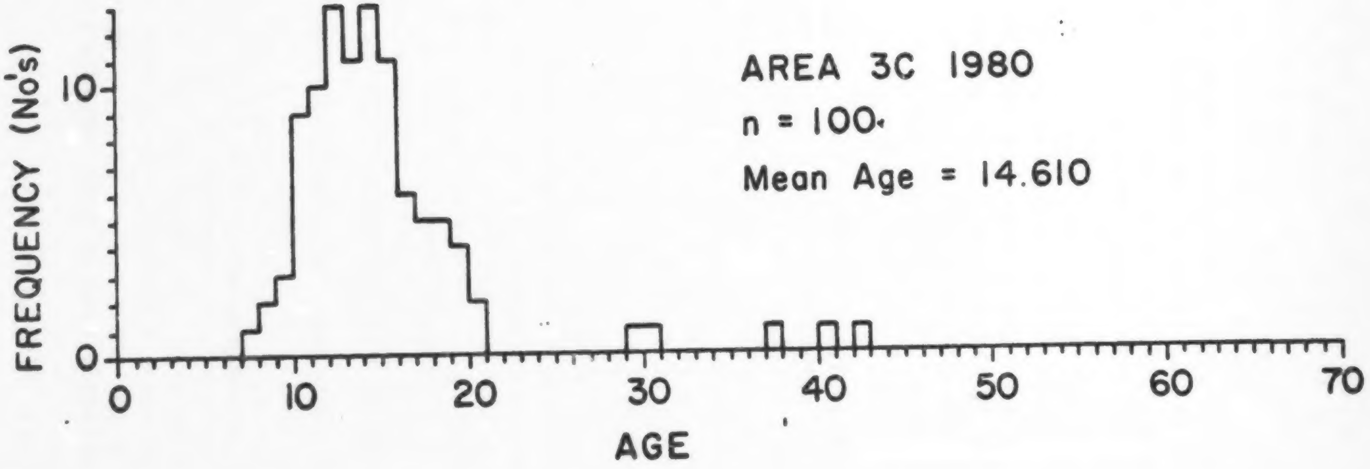


Fig. 9.1. Age frequency of Pacific ocean perch (Sebastes alutus) landings for Area 3C in 1980.

11,626 t and that of 1977 as 7,391 t. Earlier, Gunderson et al. (1977) had provided an estimate of 16,700 t for the stock biomass between 1972 and 1974. In an update of this paper, Fraidenburg et al. (1978) provided a 17,800 t biomass estimate for the 1975-77 period, however they did note a potential positive bias in the estimate.

Trawl surveys of abundance were conducted in the late 1970s over the entire stock range, although the limitations of swept-area surveys for aggregating species should be noted. While the proportion of the stock unique to the Canadian zone is not known with certainty, it is generally agreed that only about 20-25% of total biomass is resident in Canadian waters. Fraidenburg et al. (1978) reported the results of a 1977 U.S. survey showing a total stock biomass of 10,304 t (if the 7,728 t estimate in the U.S. zone represented 75% of the stock). In 1979 the U.S. conducted a second survey of the U.S. zone (Wilkins et al. 1979) and obtained an estimate of 5,711 t. The results from the Canadian zone survey conducted in 1979 showed a 6,200 t biomass; the combined 1979 total was thus 11,911 t. No additional field surveys have been conducted.

The analyses by Gunderson (1981), Kimura (1981), and Kimura and Tagart (1982) represent three different approaches to the assessment of the southern stock: cohort analysis, $\log_e$ (LPUE) analysis, and stock reduction analysis. Considering the diversity of the analyses and their necessary assumptions, there is remarkable concordance of their results (Table 9.3.). The specific limitations of the individual studies that lead to underestimation of fishing effects are: (i) the cohort analysis relies on incorrect ageing techniques and an overestimate of natural mortality; (ii) the $\log_e$ (LPUE) analysis relies on the adequacy of LPUE as an index of abundance for an aggregating species; and (iii) the stock reduction analysis assumes constant recruitment and an overestimate of natural mortality. In general, these biases are recognized by the authors but their implications are not always explicitly considered, with the exception of Kimura (1981). Concerning (ii) he commented "... one might guess that if high qualification levels are used CPUE would basically measure density of concentrations. If stock decline is largely due to fewer numbers of concentrations, it is likely that these declines would be underestimated." (ibid. 217).

In aggregate, these studies suggest a biomass for the Vancouver Area stock in the 10-15,000 t range, with a greater probability of being at the low end of the range. In addition, they suggest that the biomass surveys tend to overestimate abundance relative to other measures. Based on the experience of survey results for other aggregating species (menhaden, tunas, etc.) it would be advisable to view swept-area surveys of rockfishes as most valuable for estimating relative abundance. While such surveys are often criticized, it is not generally for their use as relative abundance indices but rather when they are inappropriately used as uncorroborated measures of absolute abundance.

(iii) Biological data

Limited biological data for this stock have been collected or processed since the previously published assessment (Stocker (ed.) 1981). Age samples collected in 1980 continue to show a stock dominated by cohorts (ages 14-16) only recently achieving full recruitment to the fishery (Fig. 9.1.). The age spectrum of the stock indicates major truncation of the

Table 9.3. Results of three different analyses of the INPFC Vancouver Area stock of Pacific ocean perch. Stock biomass in tonnes.

	Gunderson (1981)			
Year	M=0.10	M=0.15	M=0.20	Other indices[a]
1966-68	32,019	36,411	49,350	35,000
1969-1971	13,432	15,454	24,615	18,703
1972-1974	10,750	11,626	21,046	16,700
1977	8,267	7,391	15,182	10,300
1979				11,911
% change				
1966-1977	-74%	-80%	-69%	-70%

[a] See text for sources.

	Kimura (1981)	
	Relative abundance (0% qualification)[b]	(25% qualification)[b]
1955	0.94	1.01
1960	0.82	0.78
1964	0.78	0.71
1970	0.30	0.39
1975	0.17	0.39
% change 1955-1975	-82%	-61%

[b] Minimum percentage of S. alutus in vessel catch necessary for inclusion of data in analysis.

	Kimura and Tagart (1982)
1956	53,000
1969	13,250
% change 1956-1969	-75%

available spawning opportunities for cohorts recruiting after the intensive fishery of the 1965-1968 period.

(iv) Yield options

The long-term effects of the major fishery of the 1960s are difficult to predict. This difficulty arises due to the apparently widespread nature of intermittent, strong year-classes of S. alutus in the northeast Pacific, the lack of an adequate time series of catch-at-age data, and the problems of perceiving the stock-recruit relationship for this and most other rockfish stocks. In spite of this, the evident lack of strong cohorts generated after the major fishery of the mid-1960s coupled with lowered stock biomass and a truncated age spectrum cannot be ignored.

For the past three years we have recommended an experimental, controlled overharvest of the southern stock to produce a negative pulse in the age composition of the stock which could be useful in validating both biomass and age estimates. For 1985, we therefore recommend that the harvest strategy for this stock be returned to the sustainable or conservative level (Table 9.4.); conservative, sustainable, and non-sustainable yield options are non-directed fishing, 300 t and 500 t, respectively. The sustainable level is based on an F = M policy applied to the 6,200 t biomass estimate for the Canadian zone. A joint Canada-U.S. biomass survey of the southern S. alutus stock is planned for 1985. The results of that survey and analysis of the age composition data for the stock will be used to evaluate existing biomass estimates and the experimental overharvest.

The foregoing assumes yield removed in the Canadian zone is entirely supported by the proportion of the stock in the Canadian zone, rather than being supported by the stock as a whole. This tenet is unproven and a more desirable course would be to manage the 'stock' jointly with the U.S. It is particularly important to reach an accord with the U.S. concerning the appropriate level of exploitation for this and other rockfish stocks. In the case of the S. alutus stocks, the recommended TAC in U.S. waters is 600 t (Tagart and Leaman 1982), a figure which we view as a non-sustainable yield. If the fish within the two zones do constitute a single stock, then any Canadian attempts to achieve rehabilitation will be fruitless in the absence of matching policies in the U.S. zone.

(v) Landing statistics--northern stock (Area 3D)

Area 3D has never produced significant quantities of S. alutus, relative to other fishing areas. Peak historical landings were less than 300 t (Stocker 1981; Table 9.5.). A limited amount of effort is expended in this area; it is believed that this lack of effort reflects both a lack of trawlable bottom and low stock abundance.

(vi) Assessment and yield options

No new information pertaining to stock assessment is available. The recommended yield options under harvest strategies (Table 9.4.) reflect historical landings rather than any stock analysis. The conservative, sustainable and non-sustainable yield options are 250 t, 350 t and 500 t, respectively.

Table 9.4. Yield options for slope rockfishes (*S. alutus*, *S. reedi*, *S. aleutianus*). Yields in tonnes.

Area	Species	Cluster options	Harvest strategy		
			Conservative	Sustainable	Non-sustainable
3C	*S. alutus*	A	n.d.[a]	300	500
3D	*S. alutus*	A	250	350	500
5A/B	*S. alutus*	A	850	1050	1300
(Goose Is. & Mitchell's gullies)	*S. reedi*	A	200	350	500
	Slope rockfish	C	1050	1400	1800
5C (Moresby Gully)	*S. alutus*	A	1700	2000	2500
	S. reedi	A	200	250	300
	Slope rockfish	C	1900	2250	2800
5E(S)	*S. alutus*	A	400	600	1000
	S. reedi	A	400	600	1000
	S. aleutianus	A	100	250	500
Jan.-June	Slope rockfish	C	300	500	900
Sept.-Dec.	Slope rockfish	C	600	900	1300
5E(N)	*S. alutus*	A	0	n.d.	200
	S. aleutianus	A	0	n.d.	250
	Slope rockfish	C	0	n.d.	450

[a] n.d. -- non-directed fishery

Table 9.5. Canadian interviewed landings (t), effort (h), and LPUE (t/n) of *S. alutus* from Area 3D.

		Area 3D					
		Interviewed					
		0% Qualification			25% Qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1967	2.55	2.55	10.0	0.255	2.55	10.0	0.255
1968	0.41	.04	66.5	0.001	-	-	-
1969	2.49	2.49	40.5	0.062	1.26	12.5	0.101
1970	5.38	5.38	150.6	0.036	-	-	-
1971	11.39	11.39	82.0	0.139	10.32	67.0	0.154
1972	45.02	-	-	-	-	-	-
1973	-	-	-	-	-	-	-
1974	2.92	2.92	59.0	0.050	-	-	-
1975	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-
1977	1.13	1.13	7.3	0.155	.14	4.0	0.034
1978	7.05	4.48	18.9	0.237	3.45	6.9	0.499
1979	44.24	44.24	53.9	0.820	43.89	40.8	1.076
1980	144.26	143.50	300.9	0.477	126.80	190.1	0.667
1981	165.97	165.97	353.4	0.470	163.4	283.4	0.577
1982	112.86	112.13	200.8	0.558	109.92	124.3	0.884
1983	463.33	214.39	574.3	0.373	182.58	281.6	0.648
1984	100.27	28.64	115.1	0.249	24.21	26.6	0.911

[a] At least 25% of landing must be *S. alutus* for inclusion of data.

9.1.4. Queen Charlotte Sound

A. Pacific ocean perch (*S. alutus*)

There are two major 'stocks' of *S. alutus* in Queen Charlotte Sound (QCSd), the Goose Island gully (GIG) stock and the Mitchell's gully (MG) stock (Fig. 9.2.). A third stock, the Moresby gully (MOR) stock, extends into northern QCSd but it will be treated separately under Hecate Strait. This report will concentrate primarily on the GIG stock due to the relatively high quality of the time series of information on it, although some attention will be given to the MG stock.

(i) Landing statistics

Previous stock assessment documents (Ketchen 1980a; Stocker 1981; Westrheim 1980) have analyzed landing statistics in some detail and only the salient features will be repeated here.

The trawl fishery for *S. alutus* in QCSd was initiated by U.S. trawlers in the early 1950s and became a major contributer to the U.S. fishery by the mid-1950s (Table 9.6.). The Canadian component of the catch was relatively minor (<25%) for most years until the mid-1960s. Until 1972 the bulk of the catch originated from GIG, after which about 27% of the catch came from MG (Table 9.7.). A major departure from previous fishing patterns occurred in 1983 when a winter fishery, on females aggregated for spawning at the mouth of Queen Charlotte Sound, was initiated.

Fishing for *S. alutus* by foreign, distant-water fleets began in late 1964 with the arrival of a Soviet fleet. This fleet applied extensive fishing effort through 1968 and, while some effort was expended as late as 1971, catches were negligible after 1968. Japanese vessels began fishing off QCSd in 1966 and continued through 1977, the peak periods of catch were 1966-67 and 1974 (Table 9.6.).

It is difficult to determine either the precise area of operation or exact species composition of catches by the Soviet fleet. While the area of operation of the Japanese fleet is known with greater precision, the species composition problem is the same. Additional information from patrol boat sightings, over-flights and observer trips was used by Ketchen (1980b) to provide the best possible estimates of catches. Observer reports (Leaman et al. 1978) show a substantial decrease in the percentage of *S. alutus* in the "ocean perch" catches by foreign vessels over time, particularly off the mouth of QCSd. For example, the percentage of *S. alutus* in the Japanese catches had dwindled to 12% by 1977, from an estimated high of 85% in 1966.

Ketchen (1981) has provided a detailed examination of stock-specific LPUE trends for this fishery and constructed a standard LPUE index based on Canadian data (Table 9.7.). This index is consistent with previous indices and has the additional advantage of being the only index that can be used for the entire time series of data. LPUE for the Canadian fleet reached a high of 1.5 t/hr in 1965 but declined to 0.5 t/hr by 1975. The LPUE of the fleet then rose to approximately 0.8 t/hr with the imposition of catch quotas and remained relatively stable until 1982 when it dropped to 0.507 t/hr, the

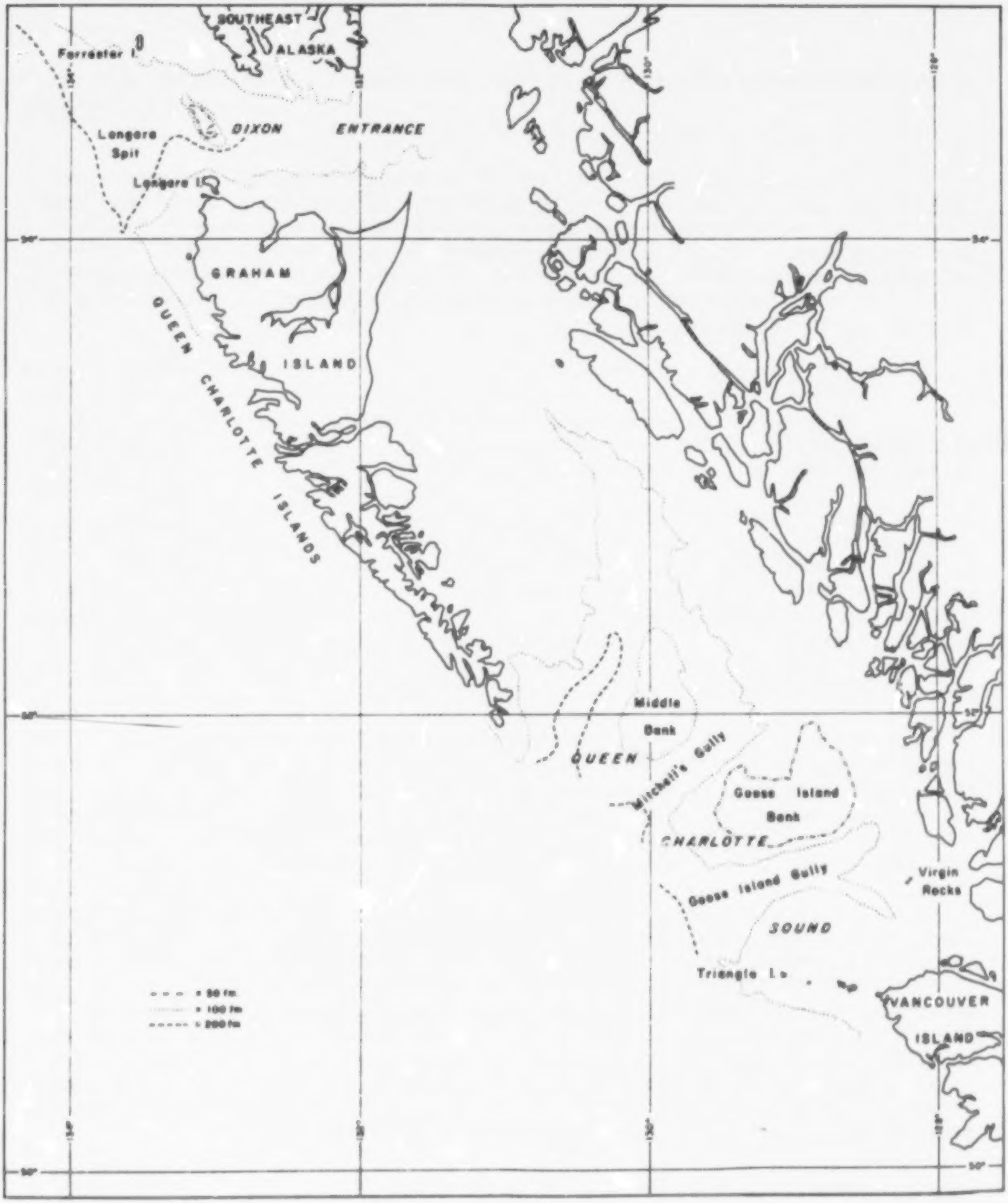

SOUTHEAST
ALASKA
Forrester I.
DIXON ENTRANCE
Langara Spit
Langara I.
GRAHAM
ISLAND
QUEEN CHARLOTTE ISLANDS
Middle Bank
QUEEN
Mitchell's Gully
Goose Island Bank
CHARLOTTE
Goose Island Gully
SOUND
Virgin Rocks
Triangle I.
VANCOUVER
ISLAND
134°
132°
130°
128°
54°
52°
50°
= 50 fm
= 100 fm
= 200 fm

Fig. 9.2. Location of major fishing areas for Pacific ocean perch in Queen Charlotte Sound.

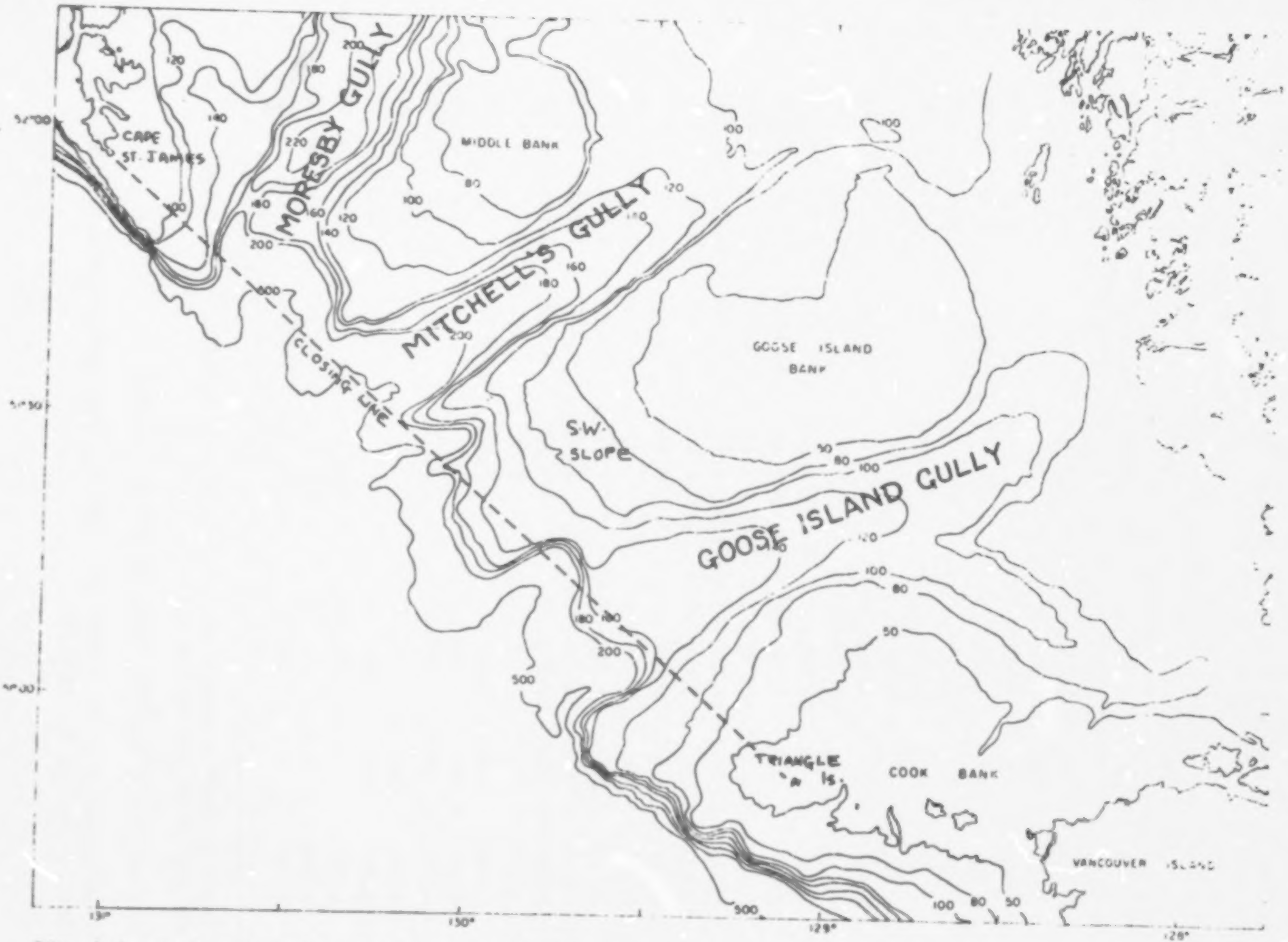

CAPE ST. JAMES
MORESBY GULLY
MIDDLE BANK
MITCHELL'S GULLY
GOOSE ISLAND BANK
S.W. SLOPE
GOOSE ISLAND GULLY
CLOSING LINE
TRIANGLE Is.
COOK BANK
VANCOUVER ISLAND
52°00'
51°30'
51°00'
131°
130°
129°
128°
120
140
180
200
220
160
100
80
50
500

Fig. 9.3. Bathymetry of Queen Charlotte Sound showing position of Goose Island Gully and Mitchell's Gully, the principal fishing grounds for Pacific ocean perch. (Depths in fathoms.) (From Ketchen 1980b.)

Table 9.6. Pacific ocean perch (*Sebastes alutus*) landings (t) by nation and LPUE (t/h) by U.S. trawlers operating in Queen Charlotte Sound.

	North America			Foreign[a]			All-nation	USA
Year	Canada	USA	Subtotal[b]	USSR	Japan	Subtotal	total	LPUE[c]
1956	141	1,093	1,234				1,234	-
1957	96	661	757	-	-	-	757	-
1958	315	616	931	-	-	-	931	-
1959	232	1,658	1,890	-	-	-	1,890	0.672
1960	356	1,323	1,679	-	-	-	1,679	0.577
1961	118	1,081	1,199	-	-	-	1,199	0.645
1962	531	1,307	1,838	-	-	-	1,838	0.661
1963	451	3,261	3,712	-	-	-	3,712	0.841
1964	419	3,088	3,507	-	-	-	3,507	0.731
1965	1,387	3,502	4,889	3,096	-	3,096	7,985	1.040
1966	2,361	5,893	8,254	12,992	888	13,880	22,134	1.132
1967	384	5,361	5,734	9,688	2,165	11,853	17,587	0.800
1968	876	5,175	6,051	3,931	2,872	6,803	12,854	0.722
1969	1,500	5,128	6,628	56	3,162	3,218	9,846	0.656
1970	1,762	4,315	6,077	-	1,863	1,863	7,940	0.710
1971	1,098	3,066	4,164	80	168	248	4,412	0.670
1972	2,196	3,366	5,562	-	1,126	1,126	6,688	0.710
1973	1,360	2,266	3,626	-	2,422	2,422	6,048	0.812
1974	1,496	2,157	3,653	-	5,632	5,632	9,285	0.610
1975	1,831	961	2,792	-	2,722	2,722	5,514	0.487
1976	1,518	448	1,966	-	1,220	1,220	3,186	0.361
1977	1,074	1,030	2,106	-	-	-	2,106	0.420
1978	1,299	37	1,336	-	-	-	1,336	0.705
1979	1,358	191	1,549	-	-	-	1,549	-
1980	1,352	179	1,531	-	-	-	1,531	-
1981	1,481	-	1,481	-	-	-	1,481	-
1982	741	-	741	-	-	-	741	-
1983	1,246	-	1,246	-	-	-	1,246	-

[a] "Intermediate" estimates as given by Ketchen (1980b); for "minimum" and "maximum" estimates see his Table 17.

[b] Revised totals for PMFC Areas 5A and 5B combined.

[c] From Gunderson et al. (1976) for 1959-74; from correspondence with Wash. State Dept. Fisheries for 1975-78.

Table 9.7. Total landings (foreign and domestic) of Pacific ocean perch, standardized LPUE and calculated total effort on the principal fishing grounds of Queen Charlotte Sound.

	Goose Island Gully			Mitchell's Gully		
Year	Total landings (t)	Standard LPUE (t/h)	Calculated effort (h)	Total landings (t)	Standard LPUE (t/h)	Calculated effort (h)
1959	1,890	0.836	2,261	-	-	-
1960	1,679	0.698	2,405	-	-	-
1961	1,199	0.797	1,504	-	-	-
1962	1,838	1.161	1,583	-	-	-
1963	3,712	1.457	2,548	-	-	-
1964	3,450	1.134	3,042	57	-	-
1965	7,478	1.491	5,015	488	0.780	626
1966	20,752	1.441	14,401	1,369	0.815	1,680
1967	12,119	1.068	11,347	5,319	1.157	4,597
1968	10,213	1.045	9,773	2,556	1.137	2,248
1969	6,872	0.763	9,007	2,945	0.995	2,960
1970	6,489	0.672	9,657	1,296	1.010	1,283
1971	3,455	0.526	6,568	813	0.954	852
1972	5,645	0.829	6,809	995	0.854	1,165
1973	3,755	0.773	4,858	2,264	1.351	1,676
1974	7,269	0.773	9,404	1,917	0.974	1,968
1975	4,209	0.507	8,302	1,151	0.989	1,164
1976	2,442	0.733	3,332	576	0.673	856
1977	1,693	0.660	2,565	256	0.551	465
1978	865	0.821	1,054	375	0.817	459
1979	951	0.799	1,190	480	0.670	716
1980	1,226	0.932	1,316	305	0.862	354
1981	801	0.760	1,054	680	4.474	152
1982	570	0.514	1,110	286	2.648	108
1983	1,215	1.257	967	31	0.929	33

second lowest on record. The rebound to 1.257 t/hr in 1983 was exclusively due to the initiation of the winter fishery noted earlier. Unfortunately, the winter fishery precluded a summer fishery in 1983 and 1984 and the LPUE index for the traditional fishing grounds is unavailable. The break in this time series combined with the probable effects of lowered exploitation of a schooling fish in these traditional areas could have major implications for its reliability in the first year(s) of the re-establishment of that fishery, in addition to the general limitations of LPUE as an index of abundance for rockfishes.

(ii) Stock units

The high catch rates of the 1983 and 1984 winter fisheries combined with a highly skewed sex ratio (≈80-85% female fish) have prompted the belief on the part of the industry that this fishery is exploiting a stock separate from that previously fished inside Queen Charlotte Sound. Pacific ocean perch have not been successfully tagged and stock delineation must be based on indirect evidence. Nonetheless, a considerable body of information supporting stock identity exists.

a) Genetic studies

Several genetic studies of S. alutus have been undertaken, most notably that of Wishard et al. (1980). It is only in the Gulf of Alaska that any genetically distinct, contiguous populations have been noted, with a separate stock being found in Prince William Sound. Allelic frequencies of protein isozymes were found to be significantly different between the Gulf of Alaska and the Washington-Oregon region. However, the lack of samples from B.C. in that study makes it difficult to determine if the differences simply represent the extremes of a continuum. Wishard's evidence supports the general hypothesis of two broad categories of S. alutus: the Gulf of Alaska type and the B.C.-Oregon type. Tsuyuki et al. (1968) found no evidence of genetic isolation of S. alutus stocks in B.C. waters. This lack does not imply that there are no distinct groups, simply that there are no genetic barriers between groups.

b) Seasonal distribution and sex ratio

The bathymetry of Queen Charlotte Sound is outlined in Figure 9.3. Figures 9.4. and 9.5. present the monthly distribution of average depth of catch for GIG and MG respectively (from Ketchen 1980b). Combining the information from these figures indicates fishing activity concentrated at the inner reaches of the gullies during the summer months (June-August) and moving to the mouth of the gullies during the autumn. Prior to 1983, little domestic effort was expended during the winter but the reappearance of deep-water catches in the spring when fishing resumed, strongly suggested overwintering in the deep water off the mouth of Queen Charlotte Sound. Similar distributions of catches have been presented for this and other areas by Alverson and Westrheim (1961), Gunderson (1977), and Snytko (1971). The winter fisheries of 1983-84 occurred in predictably deep water (330-450 m) off the mouth of Queen Charlotte Sound.

Examination of the species composition of Japanese rockfish catches from the mouth of Queen Charlotte Sound throughout the year also provides information on the seasonal distribution of S. alutus. If the stocks do indeed move in and out of the gullies with season, then there would be a lower percentage of S. alutus in the rockfish catches from the mouth of Queen Charlotte Sound during the summer months. In fact, the percentage of S. alutus in catches west and south of Triangle Island (Fig. 9.3.) reached its lowest levels in the summer months, during 1966-77. Additionally, two research cruises using commercial vessels found no significant schools of S. alutus in waters deeper than 300 m during August 1983.

Seasonal patterns of sex ratio indicate asynchronous or unilateral movement by the sexes of S. alutus. Gunderson (1971) showed that male fish predominate (80-87%) inside Queen Charlotte Sound during the winter months. Conversely, the winter fisheries of 1983-1984 at the mouth of Queen Charlotte Sound have been 80-85% female fish. Gunderson (1971), Harling et al. (1970), Ketchen (1980b), and Westrheim et al. (1974) all noted the increasing proportion of females inside Queen Charlotte Sound with the approach of summer.

The seasonal trends in sex ratio suggest that the fish encountered inside and outside Queen Charlotte Sound at different times of year are from the same stock unit. If so, then the fish caught in these two fisheries should also have the same characteristics (see Figs. 9.6. and 9.7., and following section).

c) Size/age composition

The most compelling evidence of stock delineation for Queen Charlotte Sound S. alutus comes from size and age composition differences, associated with different exploitation histories. Because of the exploitation context, these groups of fish would constitute different stocks rather than populations (Leaman (ed.) 1979). Figures 9.8. to 9.10. show the size and age compositions of the stocks around Queen Charlotte Sound. Clearly, these groups have different characteristics, and these differences persist over time. Additionally, the exploitation differences documented in Table 9.7. would give rise to exactly the differences exhibited. This implies little mixing of fish once they have recruited to the stock. It is possible that mixing occurs prior to recruitment but available age frequencies neither suggest any sustained differential recruitment among the stocks nor do they indicate the origin of recruiting cohorts.

d) Parasites

We have recently begun examination of stocks of S. alutus in Queen Charlotte Sound for the presence and infection rate of the copepod parasite Neobrachiella robusta. Preliminary work has shown both broad and narrow geographic differences of this parasite in other stocks of S. alutus. Results of the 1984 investigations are not yet available.

(iii) Stock assessment

The Queen Charlotte Sound stocks of S. alutus are probably the most intensively studied rockfish stocks on the Pacific coast. Analytic assessments have been made by Archibald et al. (1983), Gunderson (1978, 1981), and Kimura (1981). Time-series analyses have been conducted by Fraidenburg et al. (1978), Gunderson (1977), Gunderson et al. (1977), Ketchen (1981), Ketchen et al. (1978) and Westrheim et al. (1972). Biomass estimates based on trawl surveys were produced in 1965-67, 1969, 1971, 1973, 1976-77, and 1984 (Fig. 9.11.). Most of these analyses have been reviewed in previous assessment documents (Ketchen 1980a; Stocker 1981; Westrheim 1980). Of these analyses, Archibald et al. (1983) is the most comprehensive because it includes: resolution of species composition of foreign catches; effort data; time-dependent catchability; natural mortality estimates based on the newest ageing techniques; consideration of ageing error in the data series; and the correct assignment of error in the analytic model. This analysis was previously presented in detail in Stocker (1981), and the model used to reconstruct the stock history (Fournier and Archibald 1982) has been reviewed by Kimura et al. (1984).

While the reconstructed stock history presented by Archibald et al. (1983) is unchanged, the rehabilitation strategies outlined by them contained an undetected bias. The random number generator used in that work included a hardware-dependent feature that resulted in the incorporation of more stochastic error about the stock-recruit relationship than was assumed. As they had noted (p. 288) the stochastic error results in "...recruitment slightly higher than if the stochastic element was not included." The short-term (30 yr) yields associated with various fishing mortalities are altered by only a small amount (<-6%) but long-term yields (200 yr) incur a greater penalty (~-17%). In Stocker (1981) we did not present long-term yields but they were presented by Archibald et al. (1983). In that paper maximum yield was identified as ~1800 t at a biomass of 37,000 t. Table 9.8. and Figures 9.12. to 9.17. both correct these estimates and examine the sensitivity of long-term yield and biomass to the assumed natural mortality rate and the stochastic error about the stock-recruitment relationship. Previously we have identified the best estimates of M as 0.05 and the stock-recruitment standard deviation as 0.55 (Archibald et al. 1983). Using these values the maximum projected long-term yield (1550 t) occurs at a fishing mortality of F = 0.05 and a stock size of 37,900 t. The maximum sensitivity of long-term yield from the stock is associated with M, rather than F or the error about the stock-recruitment relationship (Table 9.8.). Indeed, on a proportional basis the long-term yield is 4-5 times more sensitive to assumptions about F and M than that concerning the stochastic error in recruitment. Sensitivity of yields to F and M is relatively equal within the range 0.03-0.06 but considerably greater for higher levels of M.

Since our last published stock assessment (Stocker 1981), several analyses have been completed. Kimura (1981), using a $\log_e$ (LPUE) fishing power analysis, concluded that biomass of S. alutus in Queen Charlotte Sound had been reduced by 65% over the period 1965-75; however, he believed that the stock decline was larger than this figure. Additionally, he believed that the analysis did not adequately describe the relative abundance prior to 1965 due to increasing efficiency of vessels and/or expansion of the fishing grounds. Kimura thought that biomass prior to the mid-1960s was high and contrary to his results, had been so for some time, as he had demonstrated for the Vancouver Island stock. Our backward extrapolation of age composition data for the mid-1960s, coupled with our estimate of natural mortality (M = 0.05) suggests that the biomass prior to the 1960s was quite modest in comparison with that of 1965. On the basis of trawl surveys, Westrheim (pers. comm.) believes that a similarly modest biomass gave rise to the large standing stock of ocean perch in the Gulf of Alaska during the early 1960s. It is thus possible that the results of Kimura's analysis regarding pre-1960s biomass are correct. That analysis did not produce absolute measures of abundance.

Stock Reduction Analysis (SRA) (Kimura and Tagart 1982) does produce estimates of absolute abundance using a method of conditioning the normal catch equations:

(1) $C_i = B_i F_i (1-\exp(-F_i-M)/(F_i+M)$

(2) $B_i = B_{i-1} \exp(-F_{i-1}-M) + R$ for $i>1$

plus the equation

(3) $P = B_{n+1}/B_1$

on the variables B_1, P and M; where B_1 is initial biomass, R is recruitment and P is the proportion of B_1 remaining after n years of fishing. By this process the number of unknowns in the n+1 simultaneous catch equations is reduced. A further reduction can be achieved if R is assumed a direct function of initial biomass, B_1 :

(4) $R = B_1(1-\exp(-M))$.

to achieve expected recruitment. In the first version of SRA (Kimura and Tagart 1982) recruitment was assumed constant and growth did not appear explicitly. The latter caused growth to be lumped with recruitment. In a more recent version of SRA (Kimura et al. 1984) the model has been enhanced through the incorporation of Deriso's (1980) delay-difference equation along with two methods of accounting for variable recruitment (stock-recruitment relationship and proportional recruitment). Because both versions of SRA solve for a set of simultaneous catch equations, they do not produce unique solutions without additional information to condition the equations on some fixed parameters. The major contribution of the technique is that of allowing the analyst to use intuitive estimates of some parameters and examine their effects on the assessment. For example, if one has a good estimate of B_1, the initial biomass, the recruitment can be conditioned on B_1 via equation (4) in the first version or equation (5) below for the second version.

(5) $R_1 = B_1\ [1-\exp(-M)]+_k[\exp(-2M)-\exp(-M)]$

where k is the Brody growth coefficient as used by Deriso (1980).

This equation produces the expected recruitment if the virgin biomass were in equilibrium and is called the expected recruitment line, ERL (dashed lines in the SRA plots). By fixing any of R_1, B_1, P or Fn a unique solution to the SRA can be found and from there the time series of biomass, exploitation rates and recruitment can be found.

Figures 9.18. and 9.19. show SRA plots for the first and second versions of SRA respectively, as applied to the GIG data series of Archibald et al. (1983). Additionally (Fig. 9.20.), the second version was applied to the updated data series of Table 9.7. Points on the expected recruitment line (ERL) assume 1963 biomass was virgin and that R_1 was the intersection of B_1 and the ERL. The additional information used to provide guidance as to the most appropriate solution set from Figure 9.19. was drawn from the analysis by Archibald et al. (1983), which indicated a P value of 0.17. Kimura et al. (1984) also provide algorithms to estimate equilibrium biomass and yield at fixed levels of fishing mortality and the r parameter of the stock-recruitment relationship in equation (6) below.

(6) $R_i = R_1(B_{i-k}/B_1)^r \quad i>k$

where k is the lag from birth to recruitment.

Figures 9.21.-9.24. illustrate such yield and biomass projections at four levels of assumed P.

Long-term yield is grossly sensitive to the r parameter but relatively insensitive to the assumed value of stock reduction, P. The extremes of r (0,1) represent extremes of stock resilience; at r = 0 recruitment is constant and the stock is completely resilient, while at r = 1, the stock is non-resilient and recruitment is proportional to biomass. Kimura et al. (1984) estimated r = 0.5 for S. alutus in the Gulf of Alaska. Using that value and the P = 0.17 value from Archibald et al. (1983) suggests an MSY of 986 t at a biomass of 20,700 t for the GIG stock. Kimura et al. believe this approach to MSY estimation may be conservative because of the difficulty of estimating the stock-recruitment relationship.

The MSY from the SRA is considerably below that generated by Archibald et al. (1983). We believe the latter is more realistic because of the explicit inclusion of age structure and stock-recruitment in the analysis but more importantly that they are dynamic in their contribution to stock changes. Additional benefits of their methodology include provisions for ageing error, time-dependent catchability, effort weighting, and the correct statistical formulation of the error structure for the analysis.

In addition to the SRA, the 1963-77 data for the GIG stock were also analyzed using cohort analysis (Pope 1972). The specific form of cohort analysis used was that developed by Walters (1981); unfortunately this analysis was developed on a microcomputer and is limited in the size of the catch matrix that can be examined. In particular it is limited to only 15 age groups and a subset of the 1963-77 data was therefore analyzed (ages 6-20). Due to the probable ageing errors for fish over 17 y, this limitation is not serious.

Regression analysis of fully recruited cohorts indicated M = 0.06, however it also showed M to be highly correlated with estimates of q (r = 0.99), conferring low reliability of the results. This is not surprising since M is estimated by regression methods, assuming constant q, and strong time-dependence of q was indicated by Archibald et al. (1983). For comparison, M was estimated by Archibald et al. (1981, 1983) as 0.05. Table 9.9. presents the reconstructed stock history resulting from the cohort analysis. Cohort strengths for fully recruited age groups were estimated to have been approximately 50% greater than those presented by Archibald et al. (1983). In addition, the assessment of recruitment strengths for particular cohorts is incorrectly estimated by the cohort analysis. For example, the cohort analysis indicates the 1963 cohort as being above average in abundance, yet age composition data have shown this cohort to be below average in abundance. The cohort analysis does not indicate as severe a stock decline (~-67%) as that noted in their analysis (~-83%) and suggests greater stock resilience. Tempering this finding is the lack of a stock-recruit relationship in the cohort analysis as well as some of the general limitations noted by Megrey (1983). In particular, the cohort analysis failed to estimate any time dependence of the catchability coefficient, q, whereas both Archibald et al. (1983) and Kimura (1981) noted major shifts (+ 300%) in q over the period of exploitation. Nonetheless even the cohort analysis supports the conclusion of major decline in the GIG stock.

No separate analyses have been performed in the MG stock. The contribution of this stock to the total QCSd yield has been relatively constant during the 1965-1984 period at 25±9% (95% c.i.) and available evidence indicates an exploitation history similar to that for GIG. (However, it is suspected that allocation of landings to MG and MOR may be somewhat confounded in recent parts of the data series, due to withholding of logbook information by some vessel masters). Yields are therefore assessed for the MG stock on a proportional basis to those from the GIG stock, but presented in composite.

(iv) Yield options

While there is some variance in the estimates of present stock size for S. alutus in QCSd, there is a broad consensus that it has been substantially reduced from historic levels and that rehabilitation is necessary. All of the treatments we reviewed have inherent limitations and we have adopted the analysis presented in Archibald et al. (1983) as that most accurately depicting past events as well as providing best guidance for rehabilitation. Support for this evaluation is also derived from Kimura et al. (1984) who describe the underlying basis for the analysis as, "...the most comprehensive likelihood approach to stock assessment that exists today."

Rehabilitation strategies outlined in previous assessments remain unchanged. However, the lack of adherence to the catch quotas necessary for rehabilitation in the 1982-84 period compromises achievement of this goal (Table 9.8.). It is highly probable that stock biomass has been further reduced since the adoption of this strategy (see Fig. 6 of Archibald et al. 1983). Table 9.4. provides yield options which reflect this decrease in biomass and the probable effects on stock rebuilding.

The yields associated with the conservative, sustainable and non-sustainable options are 850 t, 1050 t and 1300 t, respectively. These projected yields are lower than previous values (Stocker 1981) by approximately 15% and reflect the estimated decline of the GIG stock and a re-assessment of the contribution of the MG stock to total yield. If the conservative yield options were to be adopted over a 30 yr period, then stock size would be projected to increase by approximately 50%. A more detailed discussion of posssible rehabilition strategies for this stock is presented in Archibald et al. (1983).

Table 9.8. Two hundred year simulation of yield and biomass of Goose Island gully Sebastes alutus with varying levels of natural mortality (M), fishing mortality (F), and stochastic error about the stock-recruitment relationship (σ S-R).

Assumed M	Stoch. Std. Dev. (σ S-R)	Ann. yield (t)/pop. size (x 10^3t) @ F									
		0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
0.03	0.30	730/79.63	1270/70.23	1690/63.04	1910/54.9	2080/48.58	2110/41.8	2000/34.75	1790/28.14	1530/21.46	1110/14.36
0.05	0.30	530/60.05	910/52.43	1190/46.12	1280/38.55	1310/32.19	1210/25.18	970/17.73	700/11.54	430/6.37	220/2.95
0.07	0.30	370/43.14	600/35.87	720/29.38	680/21.62	580/14.94	400/8.82	230/4.33	120/2.04	50/0.82	20/0.30
0.10	0.30	140/17.43	160/10.49	130/5.66	70/2.49	40/1.04	20/0.39	0/0.14	0/0.05	0/0.02	0/0.01
0.15	0.30	0/0.12	0/0.04	0/0.01	-	-	-	-	-	-	-
0.03	0.55	760/83.82	1350/74.57	1830/68.14	2060/59.34	2300/53.8	2390/47.03	2310/40.01	2140/33.96	2010/28.11	1580/20.48
0.05	0.55	570/64.5	1000/57.1	1330/51.5	1440/43.5	1550/37.9	1510/31.2	1300/23.7	1040/17.5	770/11.3	440/6.0
0.07	0.55	410/48.13	690/41.18	880/35.33	850/27.22	810/21.01	660/14.19	420/8.01	250/4.49	130/2.0	60/0.79
0.10	0.55	180/23.42	250/15.95	230/10.0	140/4.92	90/2.39	40/0.96	20/0.36	10/0.16	0/0.06	0/0.02
0.15	0.56	0/0.31	0/0.10	0/0.04	0/0.01	0/0.01	-	-	-	-	-
0.03	0.63	780/85.65	1380/76.50	1890/70.34	2120/60.32	2400/56.08	2510/49.26	2440/42.27	2290/36.47	2230/31.05	1800/23.23
0.05	0.63	590/66.53	1030/59.28	1400/53.85	1510/45.63	1660/40.45	1640/33.75	1450/26.31	1200/20.27	950/13.93	580/7.87
0.07	0.63	430/50.28	730/43.53	940/37.88	930/29.69	920/23.76	780/16.85	530/10.11	340/6.08	190/2.87	80/1.19
0.10	0.63	200/26.06	290/18.62	280/12.35	180/6.42	120/3.34	60/1.41	30/.55	10/.25	10/.09	0/0.03
0.15	0.63	0/.47	0/.16	0/.06	0/.02	0/0.01	-	-	-	-	-

Table 9.9. Number of fish (x 10^4) at age for Goose Island gully Pacific ocean perch, estimated by cohort analysis of 1963-1977 catch and effort data.

	Year														
Age	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
06	805	588	474	566	1345	1802	1902	1597	1102	972	365	289	237	230	77
07	1291	758	554	447	523	1261	1667	1783	1470	1033	912	343	264	215	211
08	1218	1210	714	518	416	493	1162	1550	1659	1366	961	857	321	245	196
09	1612	1139	1132	669	478	390	434	1052	1394	1550	1248	898	782	300	226
10	1910	1507	1068	1043	601	432	336	345	816	1271	1413	1150	786	710	278
11	3378	1764	1403	958	912	514	371	272	268	663	1084	1293	987	682	649
12	1346	3077	1642	1259	766	774	432	311	218	209	480	935	1073	852	607
13	1134	1179	2833	1388	961	590	622	371	273	190	192	376	704	890	757
14	742	983	1035	2414	1003	718	402	496	312	249	155	155	240	564	772
15	559	659	875	846	1493	719	544	306	433	272	221	131	102	197	479
16	415	504	589	755	457	1173	498	420	234	391	225	200	97	76	170
17	527	370	460	520	495	314	971	387	351	180	344	196	166	78	62
18	298	477	337	399	371	389	210	849	316	300	130	310	153	141	67
19	389	263	439	293	301	266	308	144	733	273	246	105	264	129	124
20	216	350	222	384	216	241	200	257	108	652	226	213	73	232	113
Total	15840	14828	13777	12459	10338	10076	10059	10140	9687	9571	8202	7451	6249	5541	4788

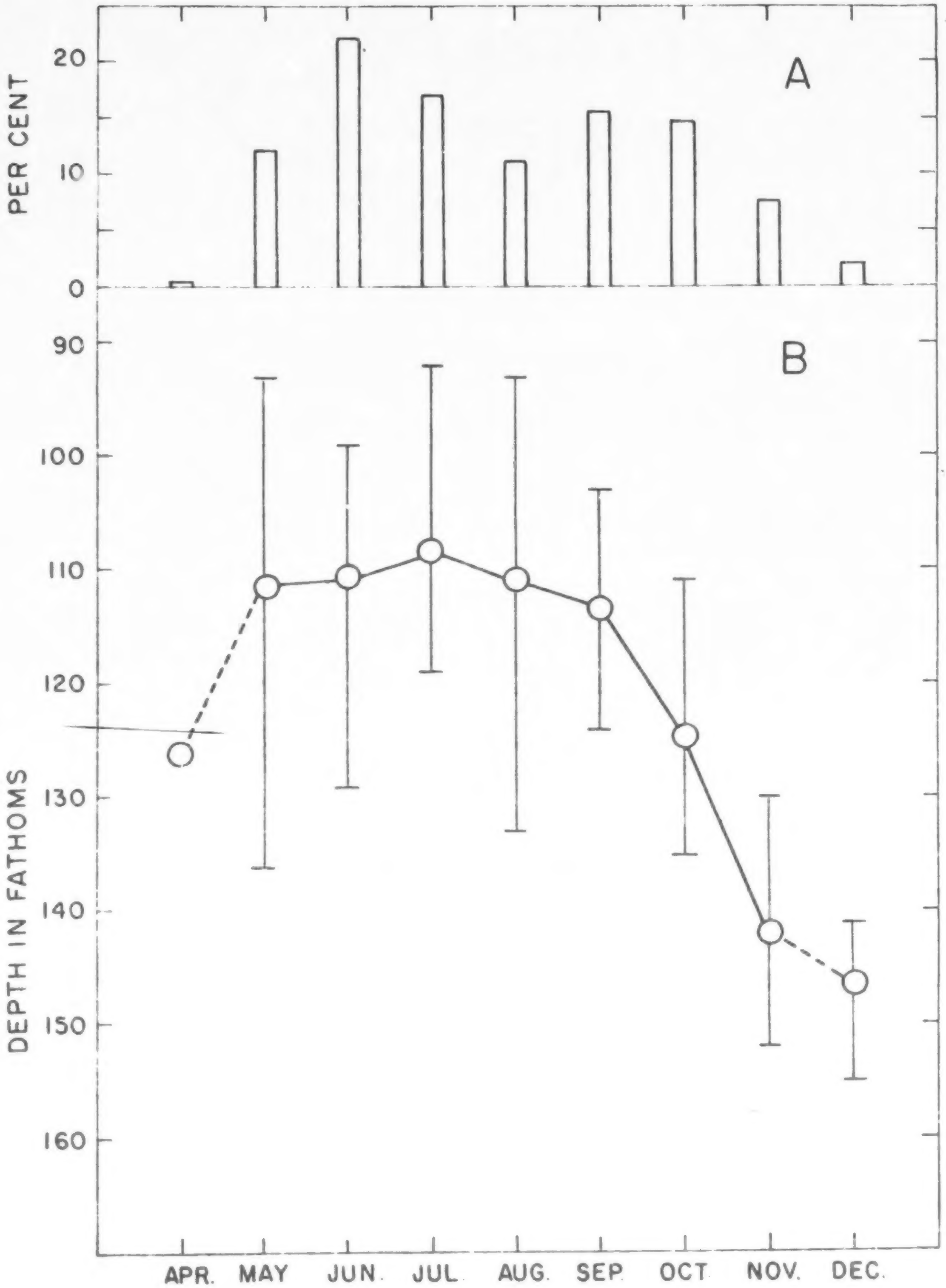


Fig. 9.4.(A) Average monthly landings of Pacific ocean perch by Canadian trawlers operating on grounds associated with Goose Island Gully (1963-78), and (B) mean and range of average depths of fishing (weighted to catch) during the same period. (From Ketchen 1980 b).

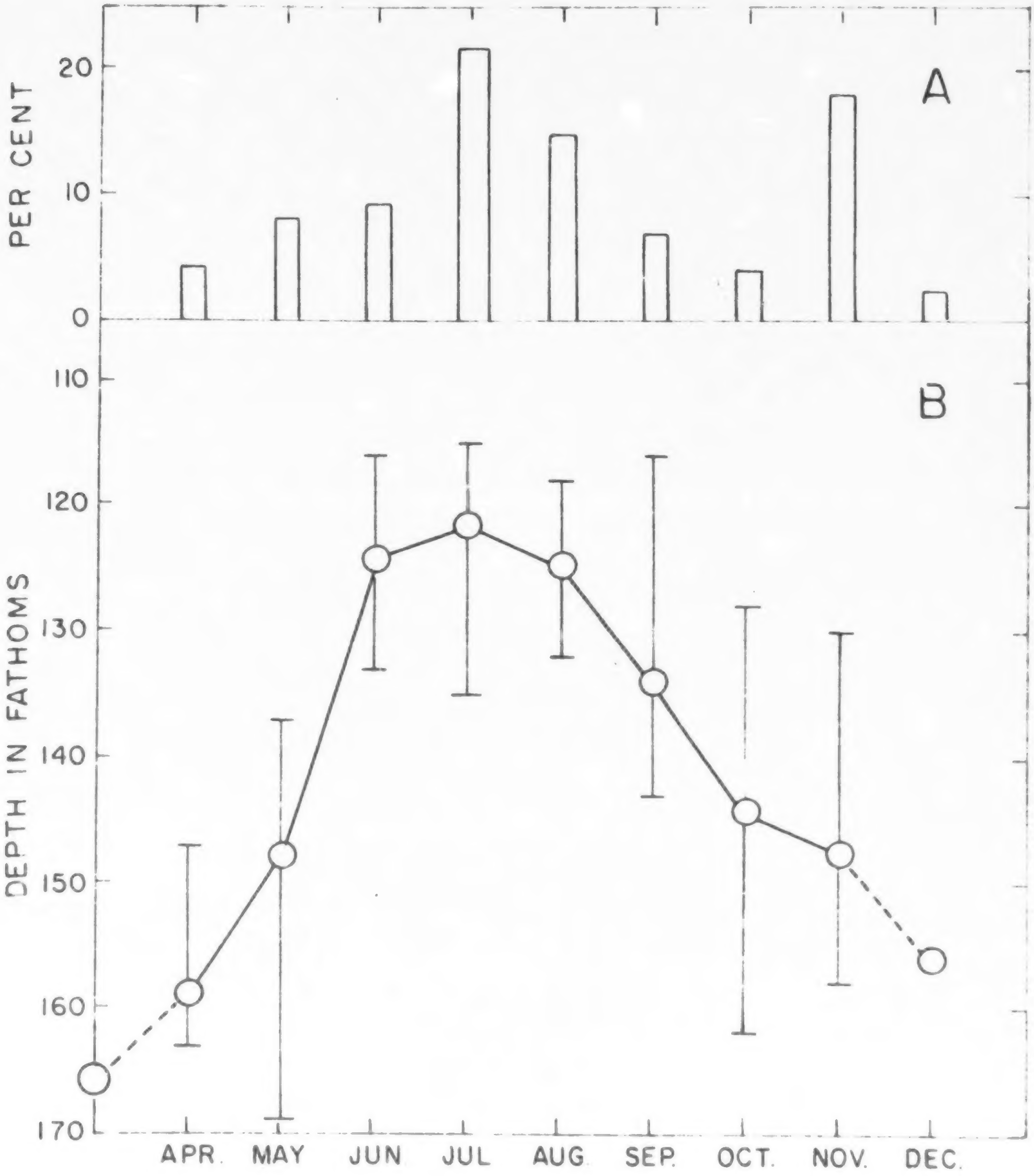


Fig. 9.5.(A) Average monthly landings of Pacific ocean perch by Canadian trawlers operating on grounds associated with Mitchell's Gully (1972-78), and (B) mean and range of average depths of fishing (weighted to catch) during the same period. (From Ketchen 1980b.)

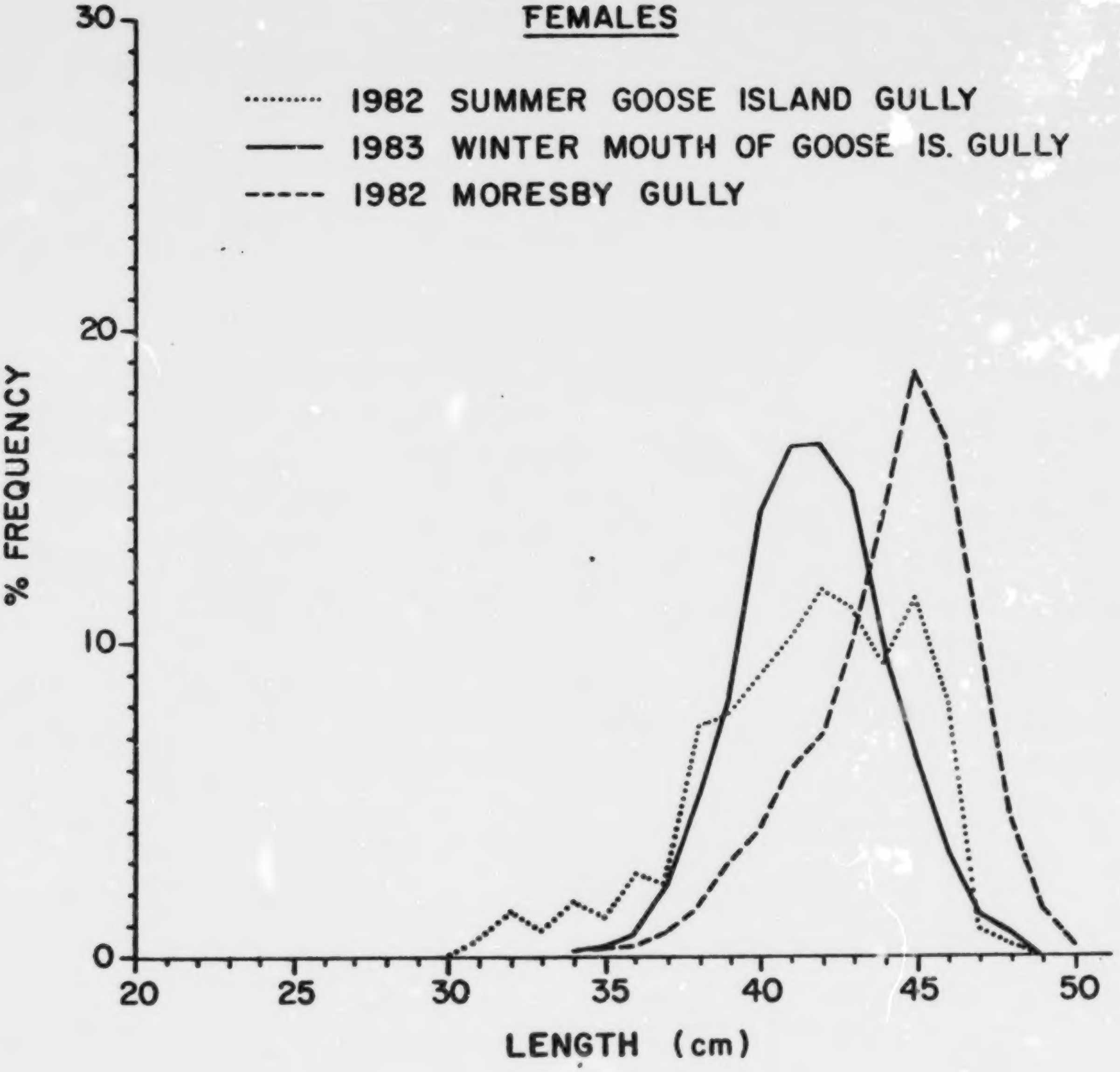


Fig. 9.6. Length frequency of Pacific ocean perch females from winter and summer fisheries in Goose Island gully and the summer fishery in Moresby gully 1982-83.

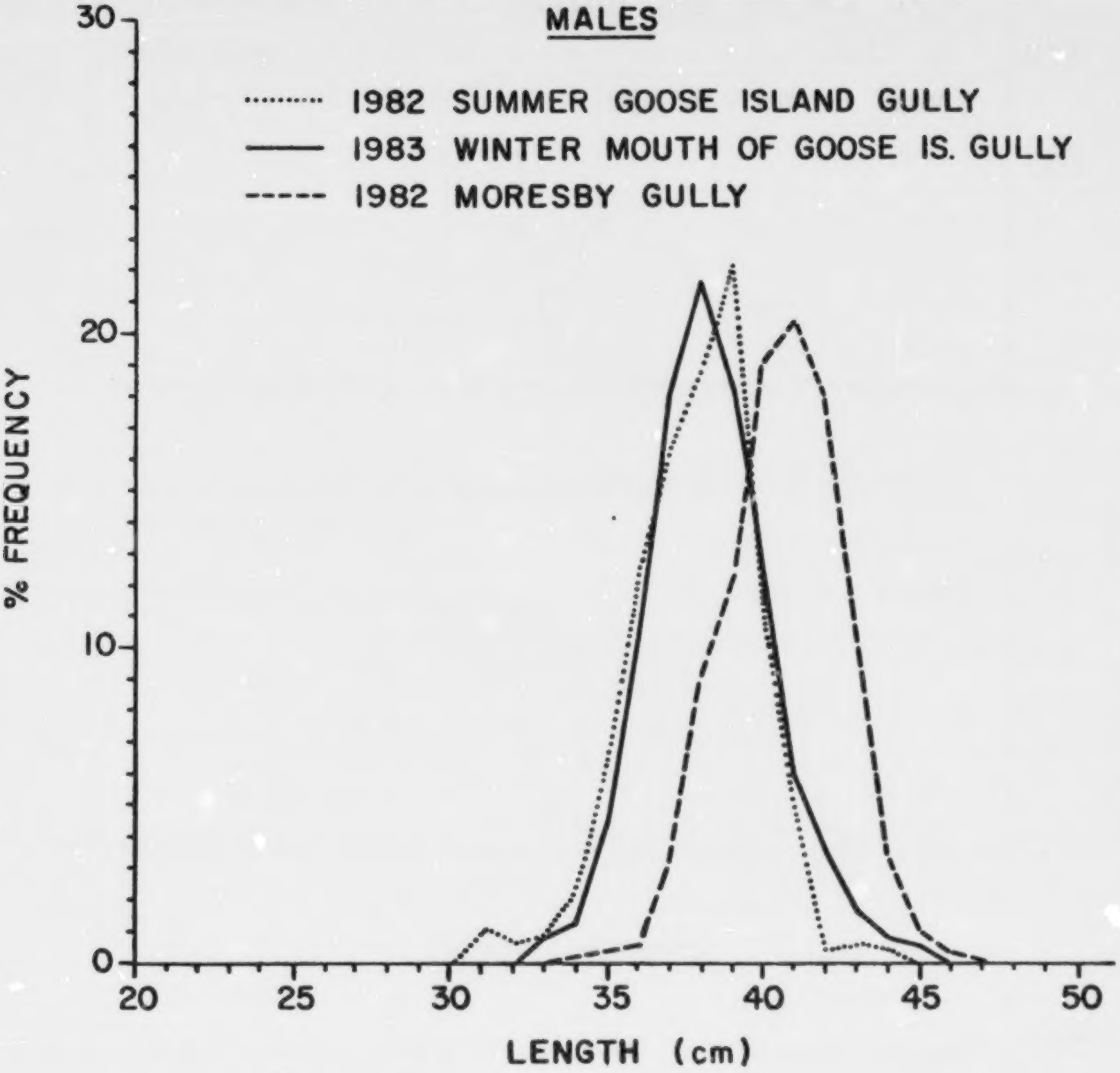


Fig. 9.7. Length frequency of Pacific ocean perch males from winter and summer fisheries in Goose Island gully and the summer fishery in Moresby gully, 1982-83.

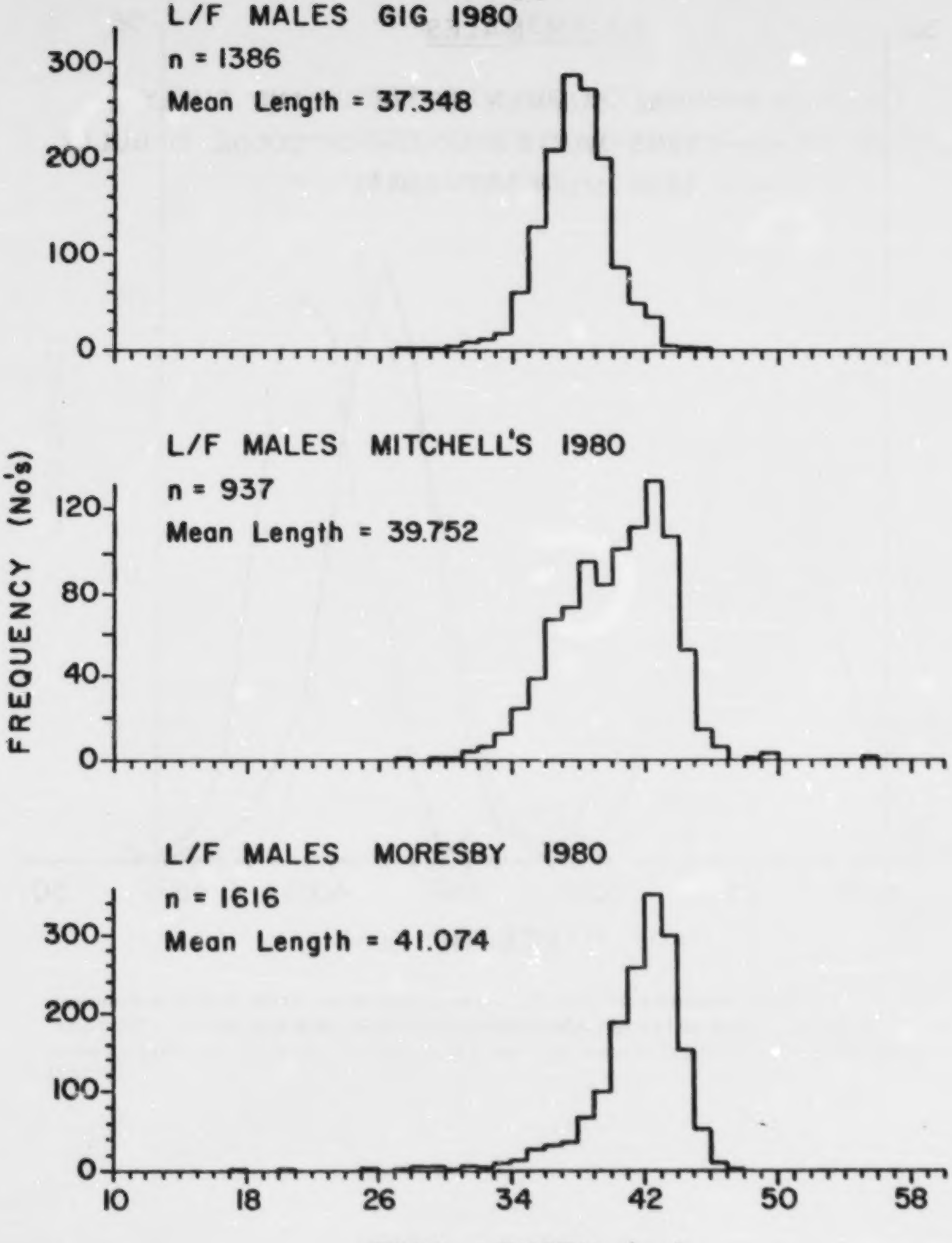
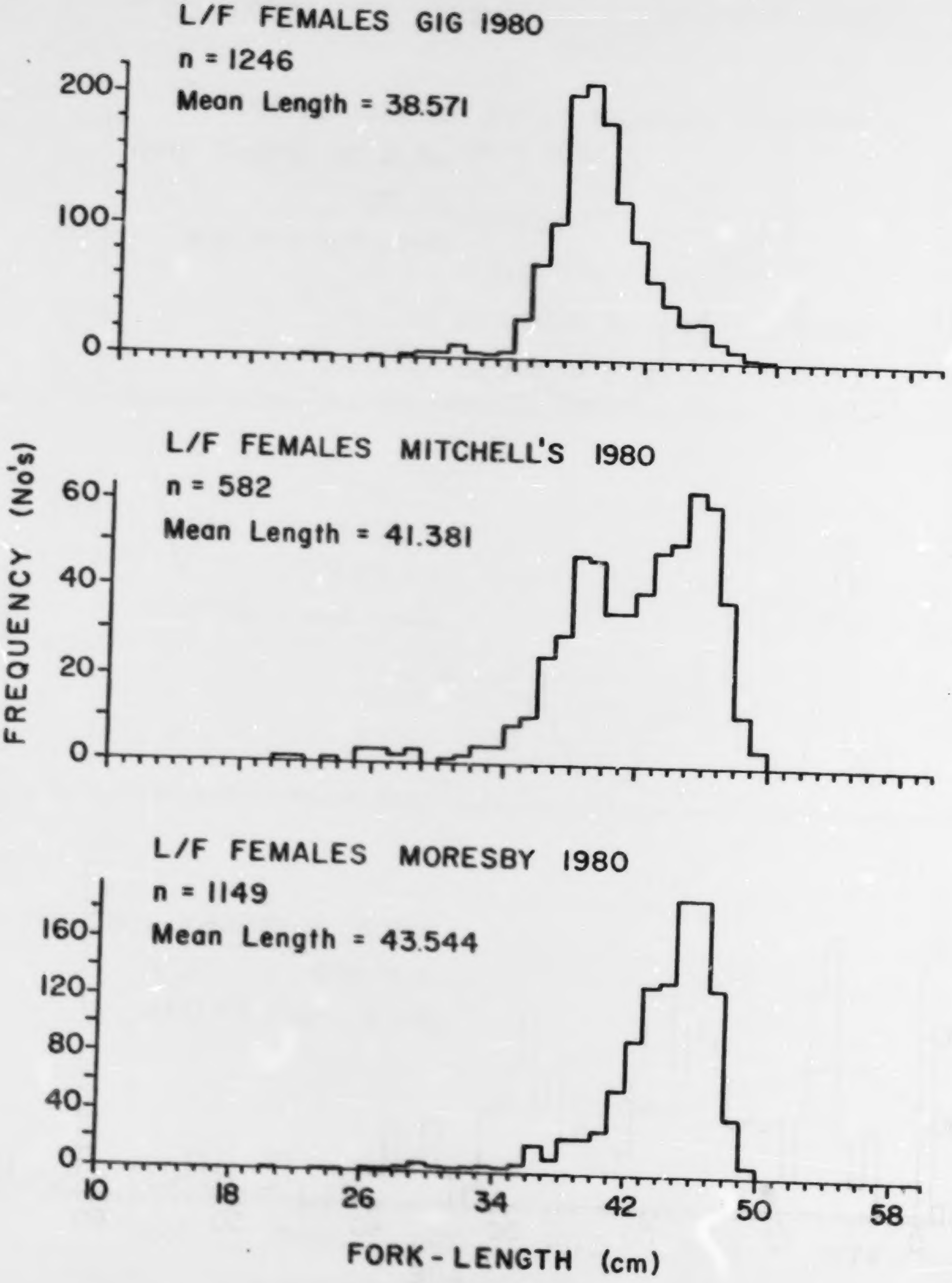


Fig. 9.8. Length frequency of Pacific ocean perch males from the three gullies surrounding Queen Charlotte Sound in 1980.



L/F FEMALES GIG 1980

n = 1246

Mean Length = 38.571

L/F FEMALES MITCHELL'S 1980

n = 582

Mean Length = 41.381

L/F FEMALES MORESBY 1980

n = 1149

Mean Length = 43.544

Fig. 9.9. Length frequency of Pacific ocean perch females from the three gullies surrounding Queen Charlotte Sound in 1980.

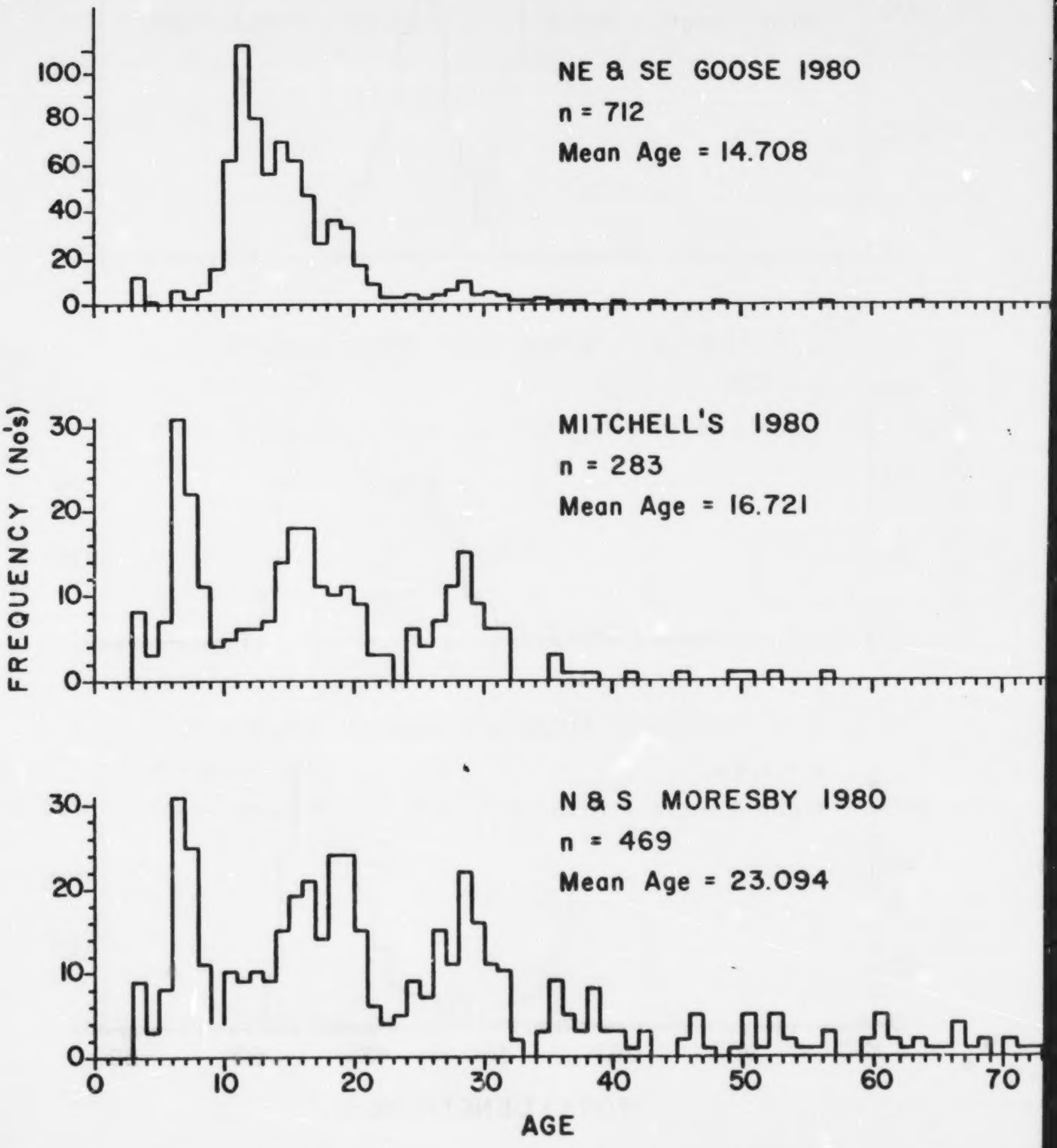


Fig. 9.10. **Age frequencies of Pacific ocean perch from the three gullies surrounding Queen Charlotte Sound in 1980.**

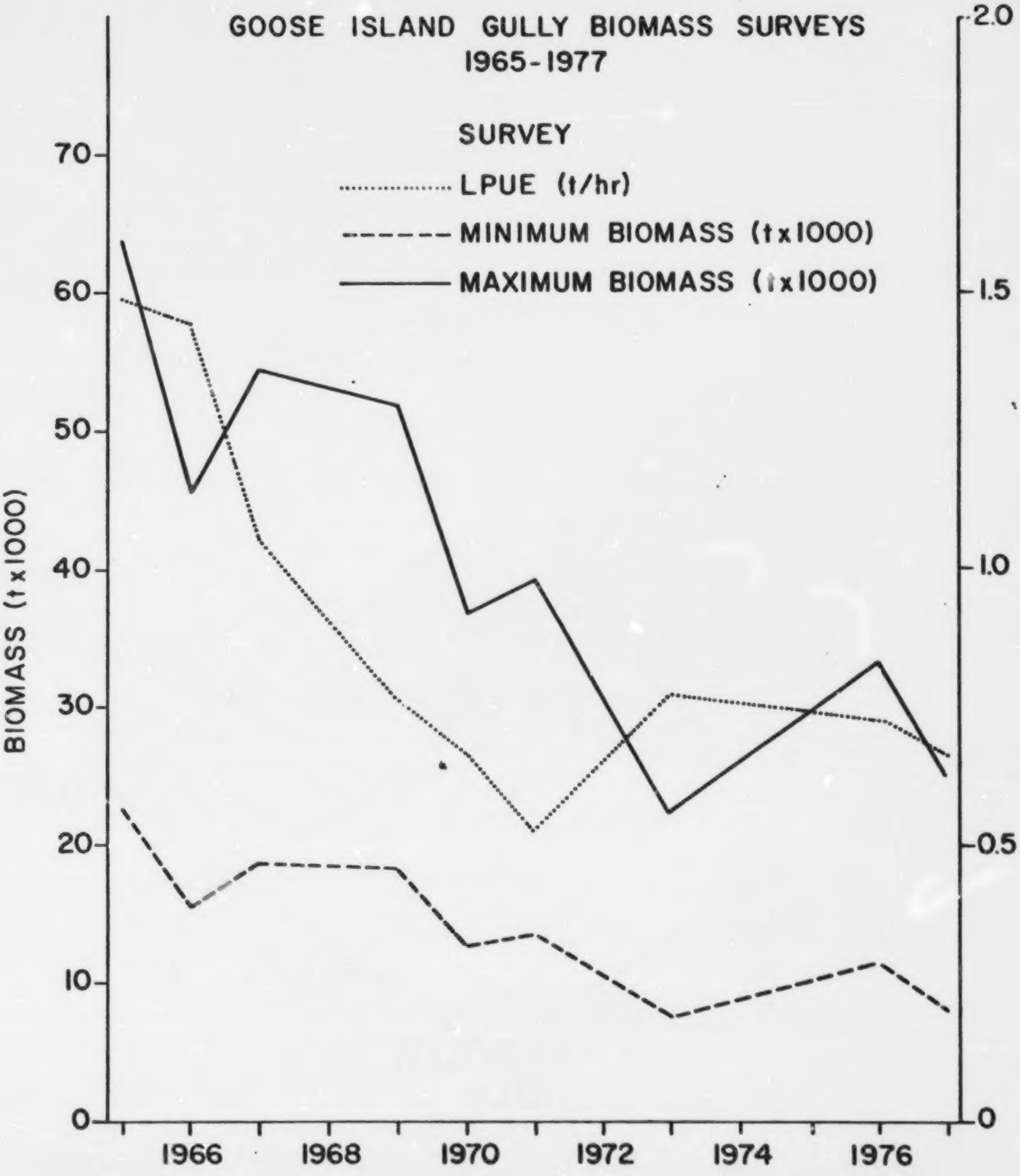


Fig. 9.11. Biomass estimates and LPUE (t/hr) for Pacific ocean perch derived from trawl surveys in Goose Island gully.

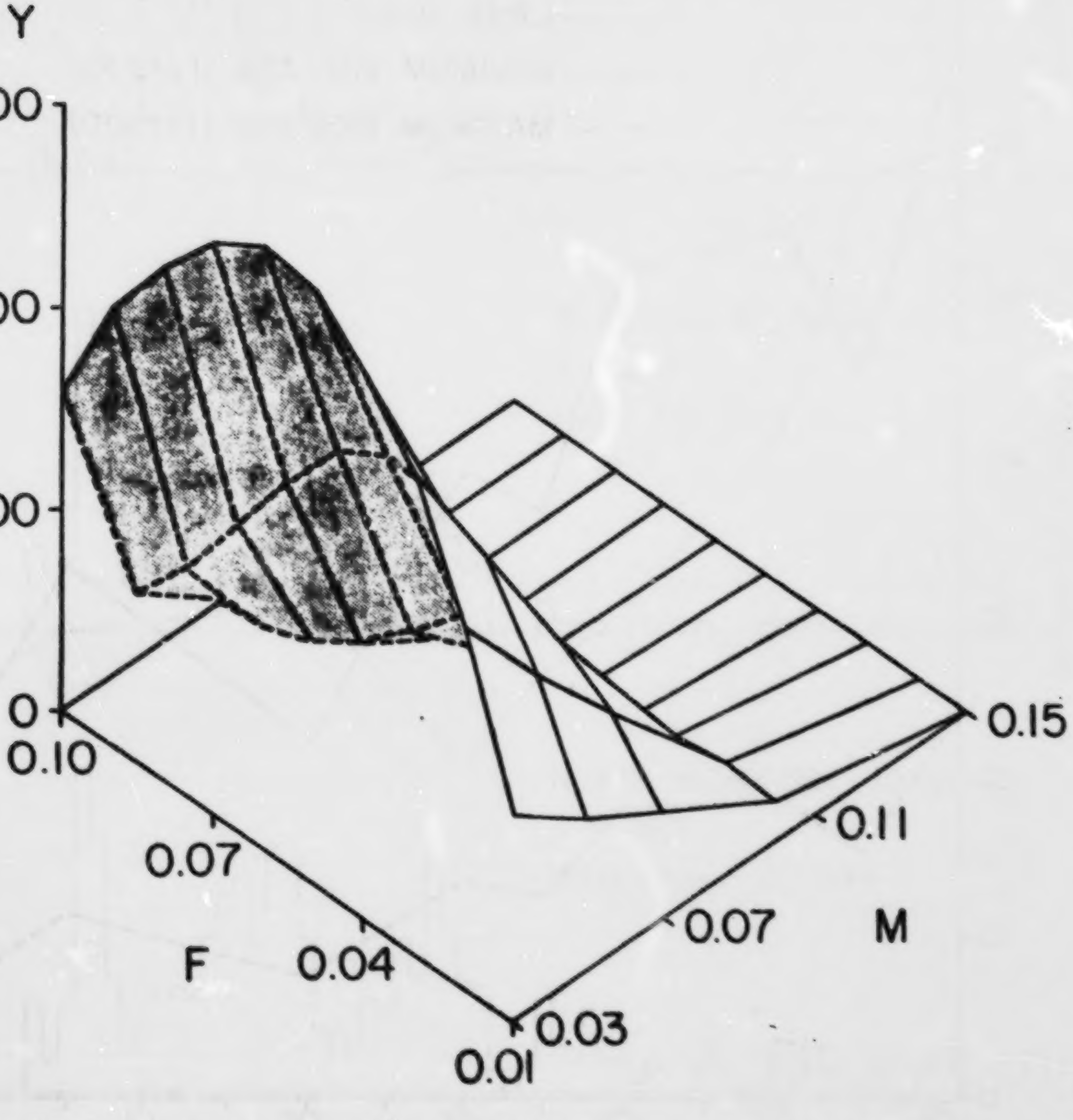


Fig. 9.12. Simulated yields (t) of Pacific ocean perch in Goose Island gully as a joint function of instantaneous fishing (F) and natural (M) mortality. Simulations are for yields after 200 yr with a standard deviation of the stochastic error in the stock-recruitment relationship of 0.30.

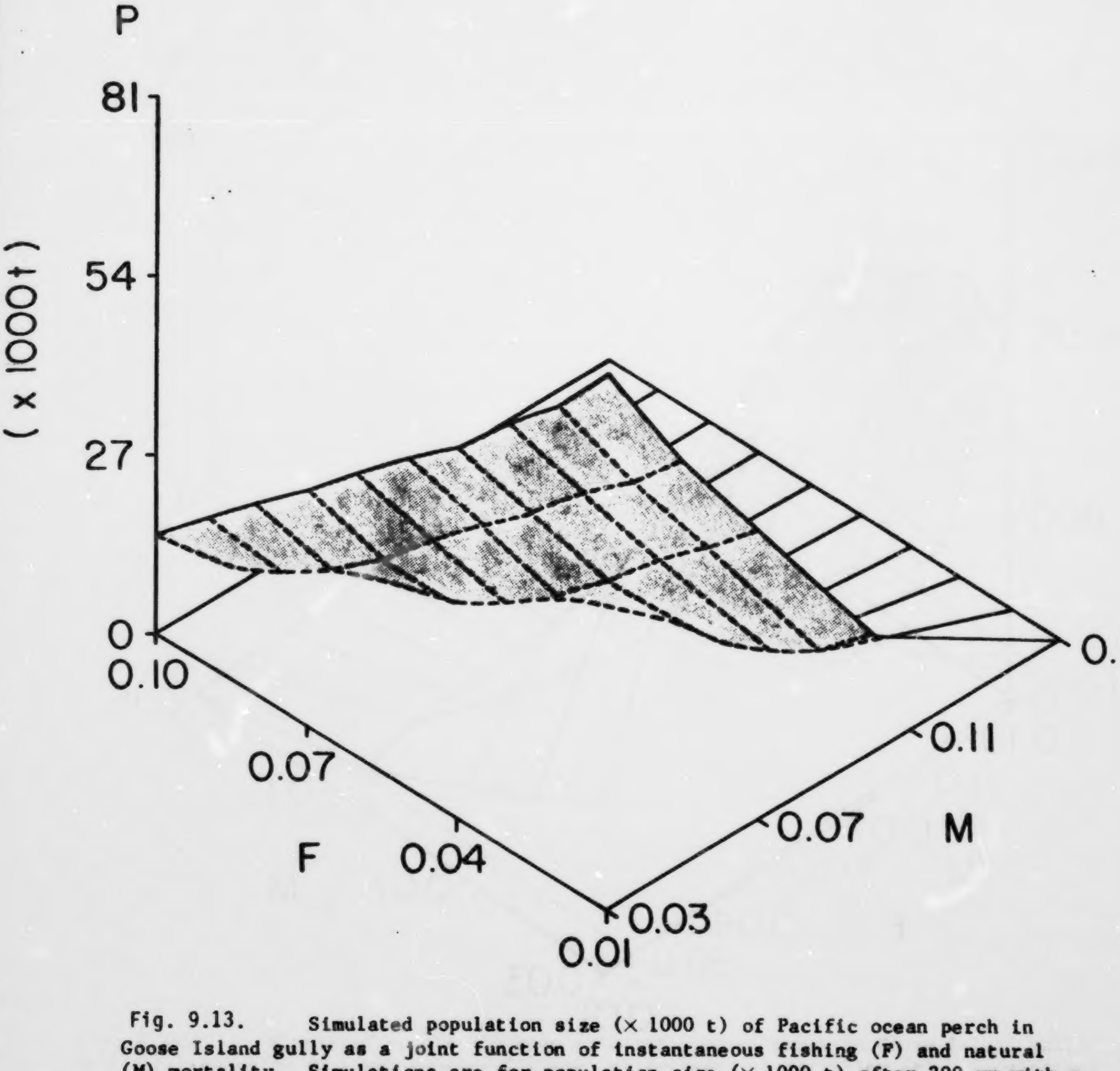


Fig. 9.13. Simulated population size (× 1000 t) of Pacific ocean perch in Goose Island gully as a joint function of instantaneous fishing (F) and natural (M) mortality. Simulations are for population size (× 1000 t) after 200 yr with a standard deviation of the stochastic error in the stock-recruitment relationship of 0.30.

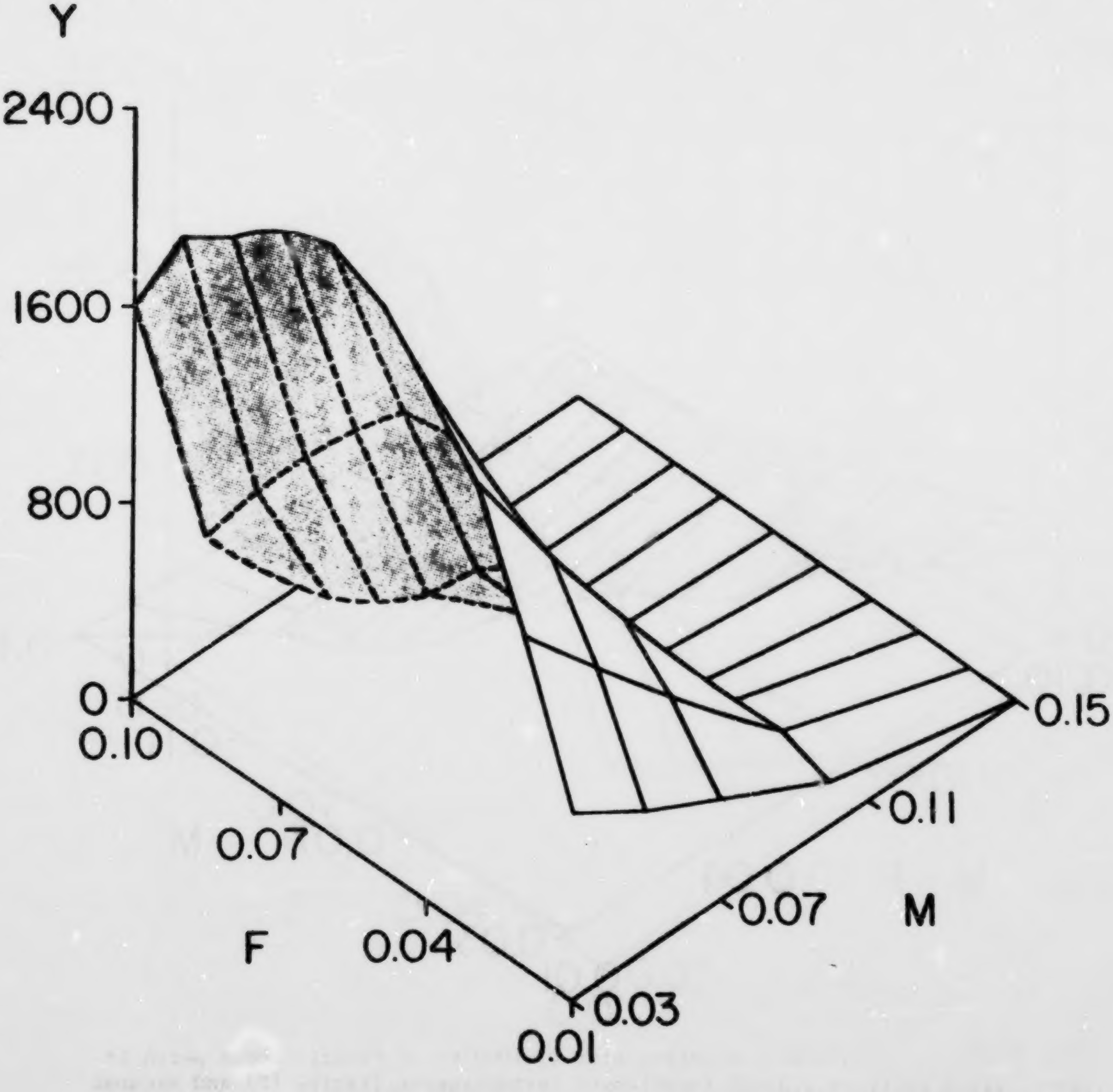


Fig. 9.14. Simulated yields (t) of Pacific ocean perch in Goose Island gully as a joint function of instantaneous fishing (F) and natural (M) mortality. Simulations are for yields after 200 yr with a standard deviation of the stochastic error in the stock-recruitment relationship of 0.55.

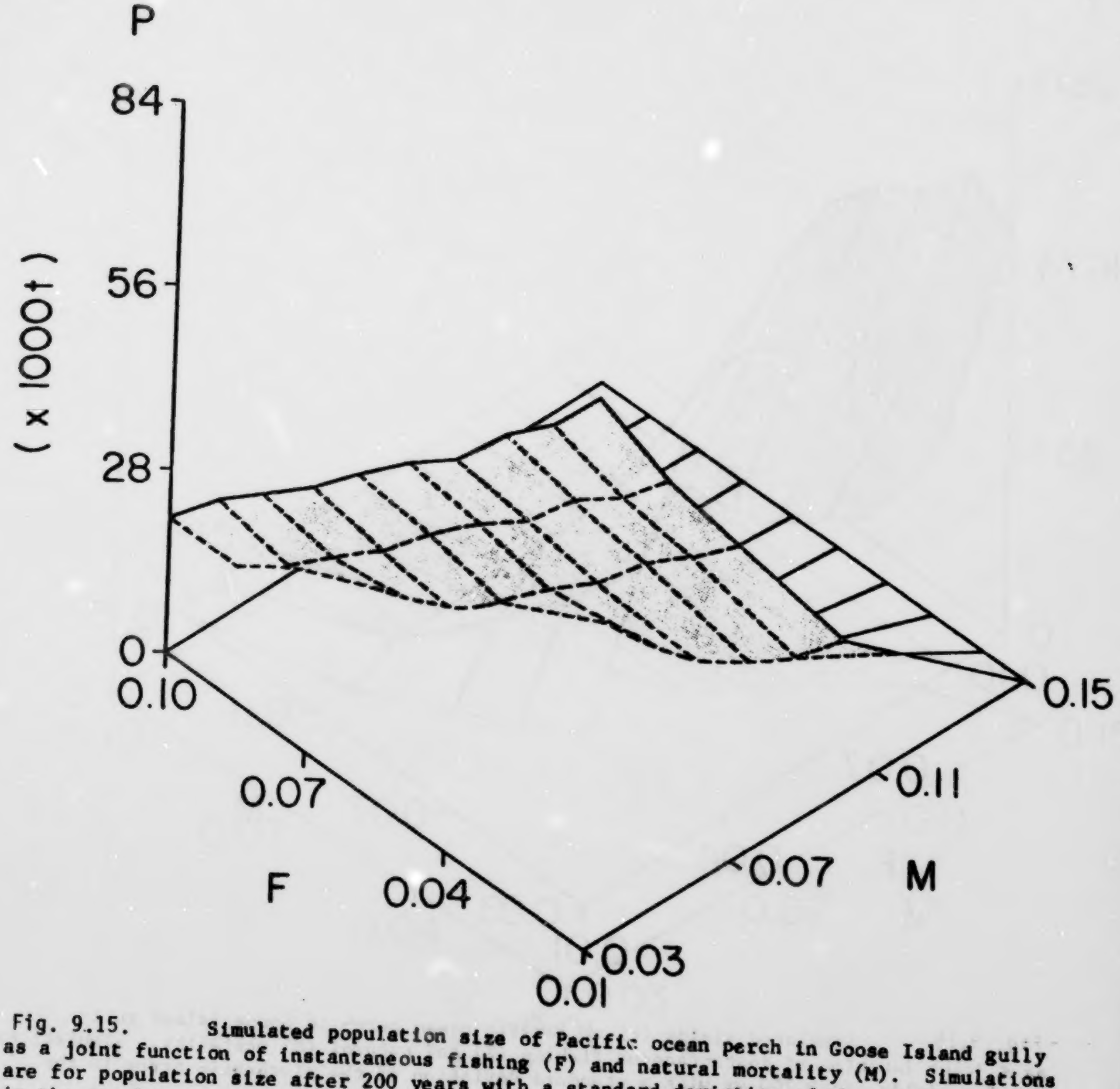


Fig. 9.15. Simulated population size of Pacific ocean perch in Goose Island gully as a joint function of instantaneous fishing (F) and natural mortality (M). Simulations are for population size after 200 years with a standard deviation of the stochastic error in the stock-recruitment relationship of 0.55.

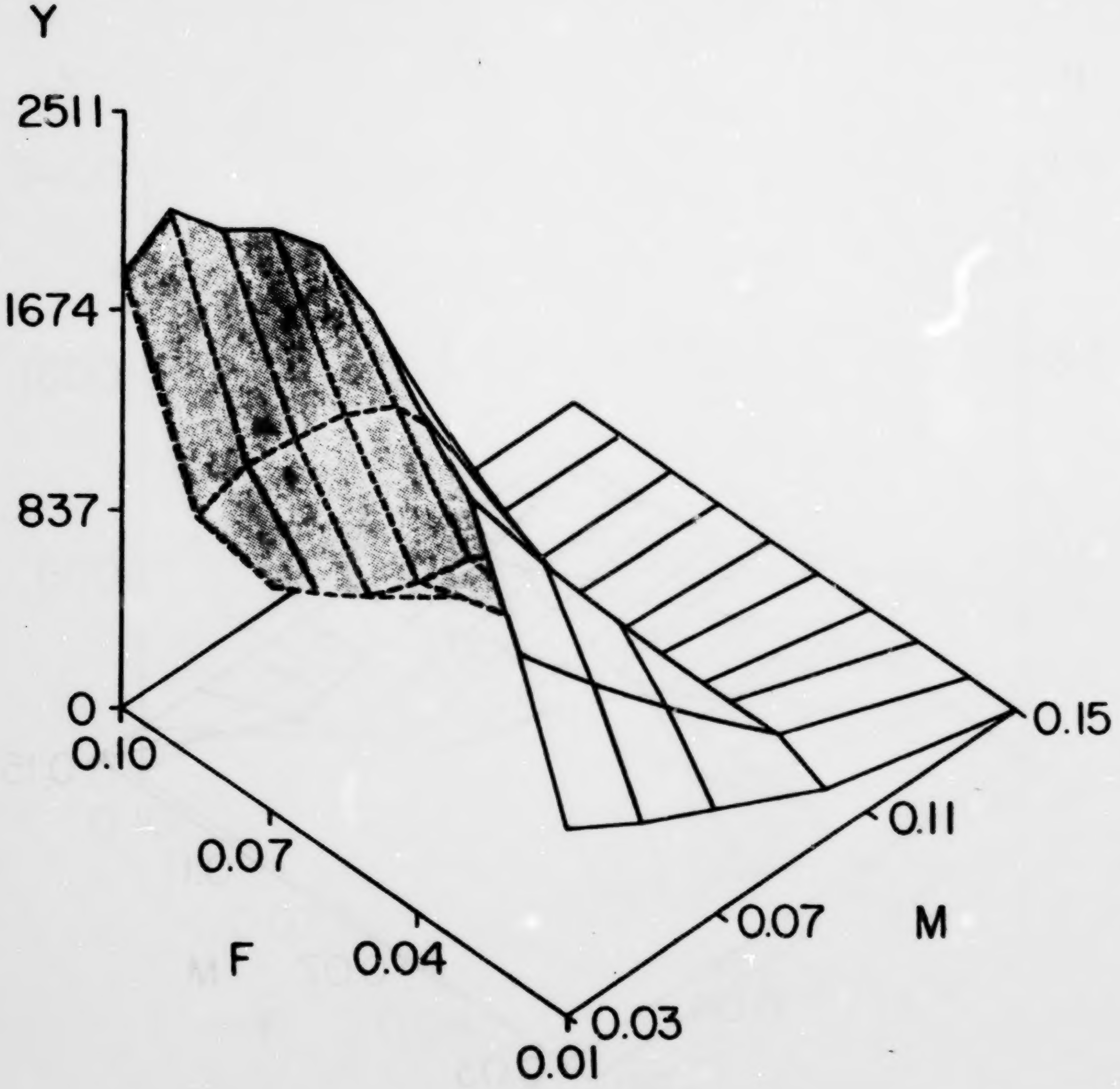


Fig. 9.16. Simulated yields (t) of Pacific ocean perch in Goose Island gully as a joint function of instantaneous fishing (F) and natural (M) mortality. Simulations are for yields after 200 yr with a standard deviation of the stochastic error in the stock-recruitment relationship of 0.63.

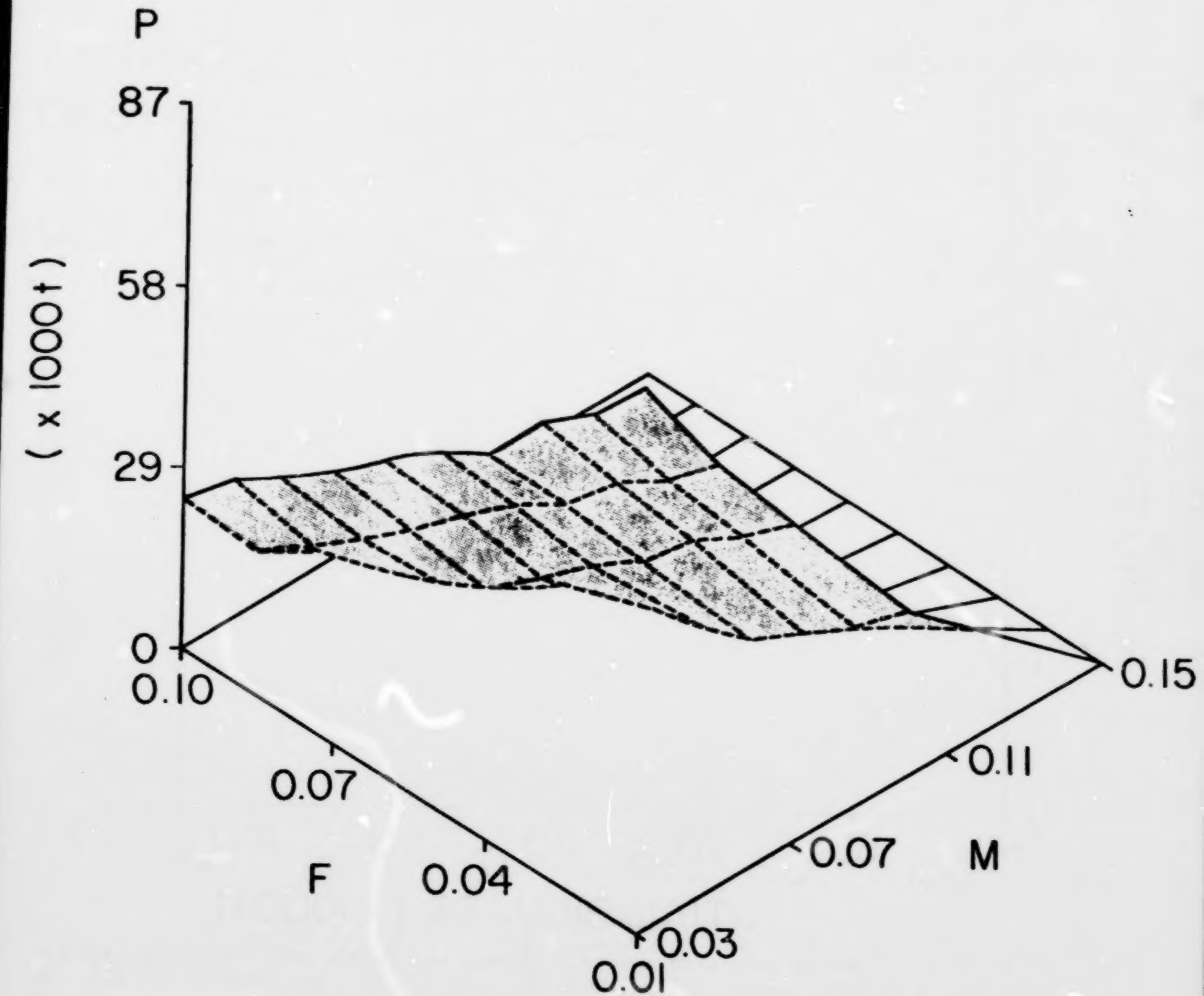


Fig. 9.17. Simulated population size of Pacific ocean perch in Goose Island gully as a joint function of instantaneous fishing (F) and natural (M) mortality. Simulations are for population size after 200 yr with a standard deviation of the stochastic error in the stock-recruitment relationship of 0.63.

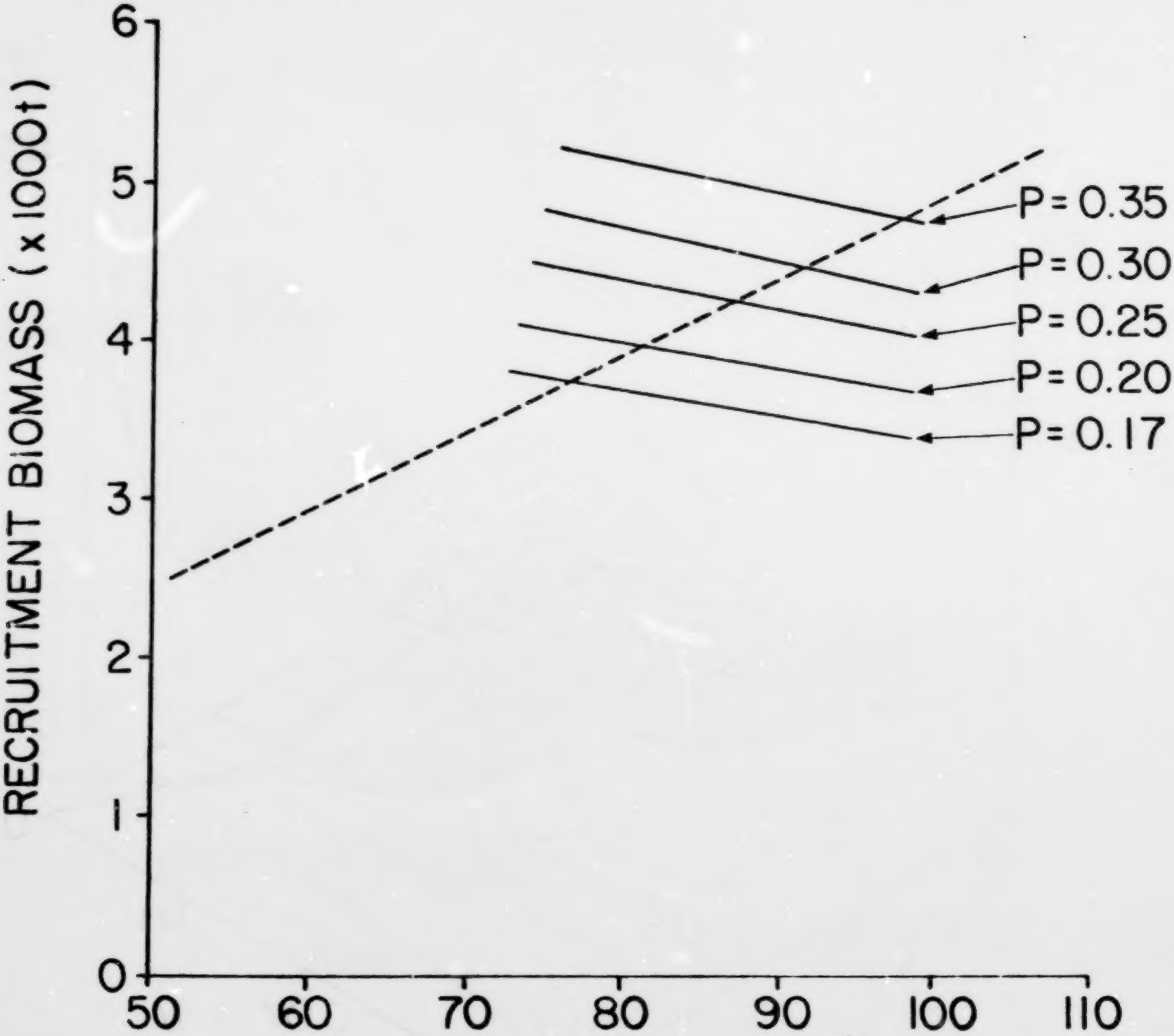


Fig. 9.18. Stock Reduction Analysis (Kimura and Tagart 1982) plot for Pacific ocean perch in Goose Island gully (1963-77) using M=0.05. See section 9.2.3.3. for additional details.

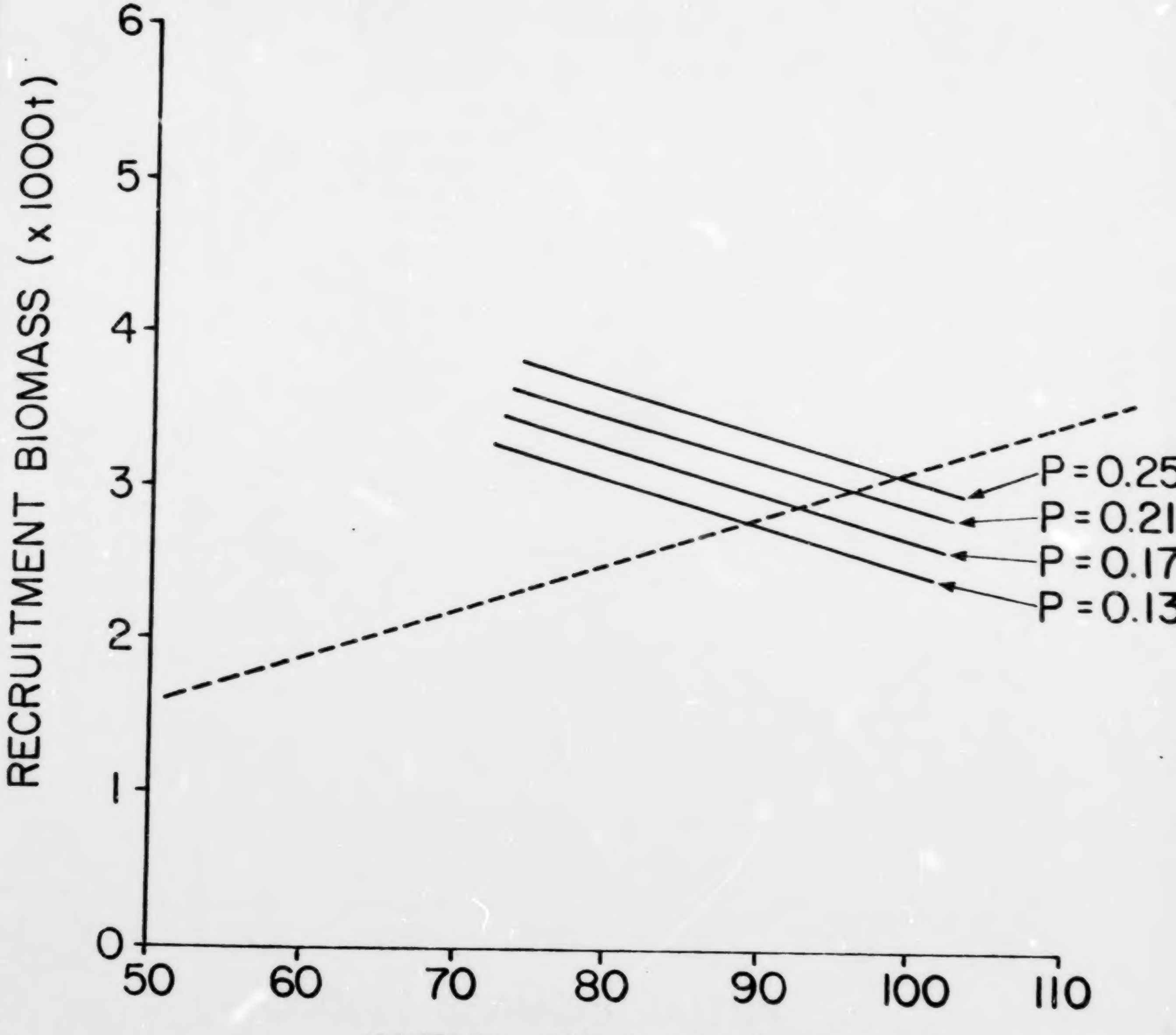


Fig. 9.19. Stock Reduction Analysis (Kimura et al. 1984) plot for Pacific ocean perch in Goose Island gully (1963-77) using M=0.05, r=0.5, and P=0.38. See section 9.2.3.3 for additional details.

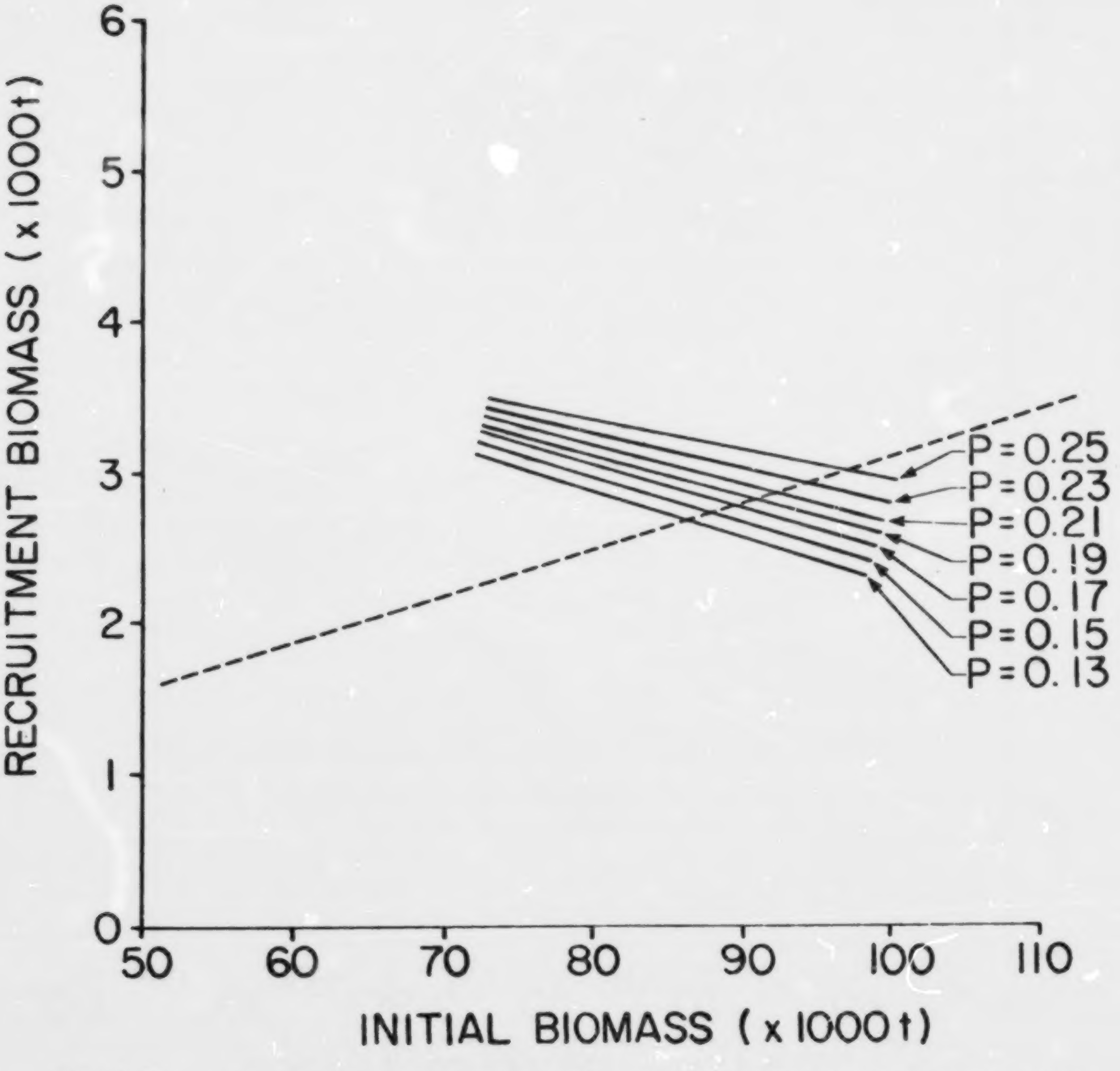


Fig. 9.20. Stock Reduction Analysis (Kimura et al. 1984) plot for Pacific ocean perch in Goose Island gully (1963-83) using M=0.05. See section 9.2.3.3. for additional details.

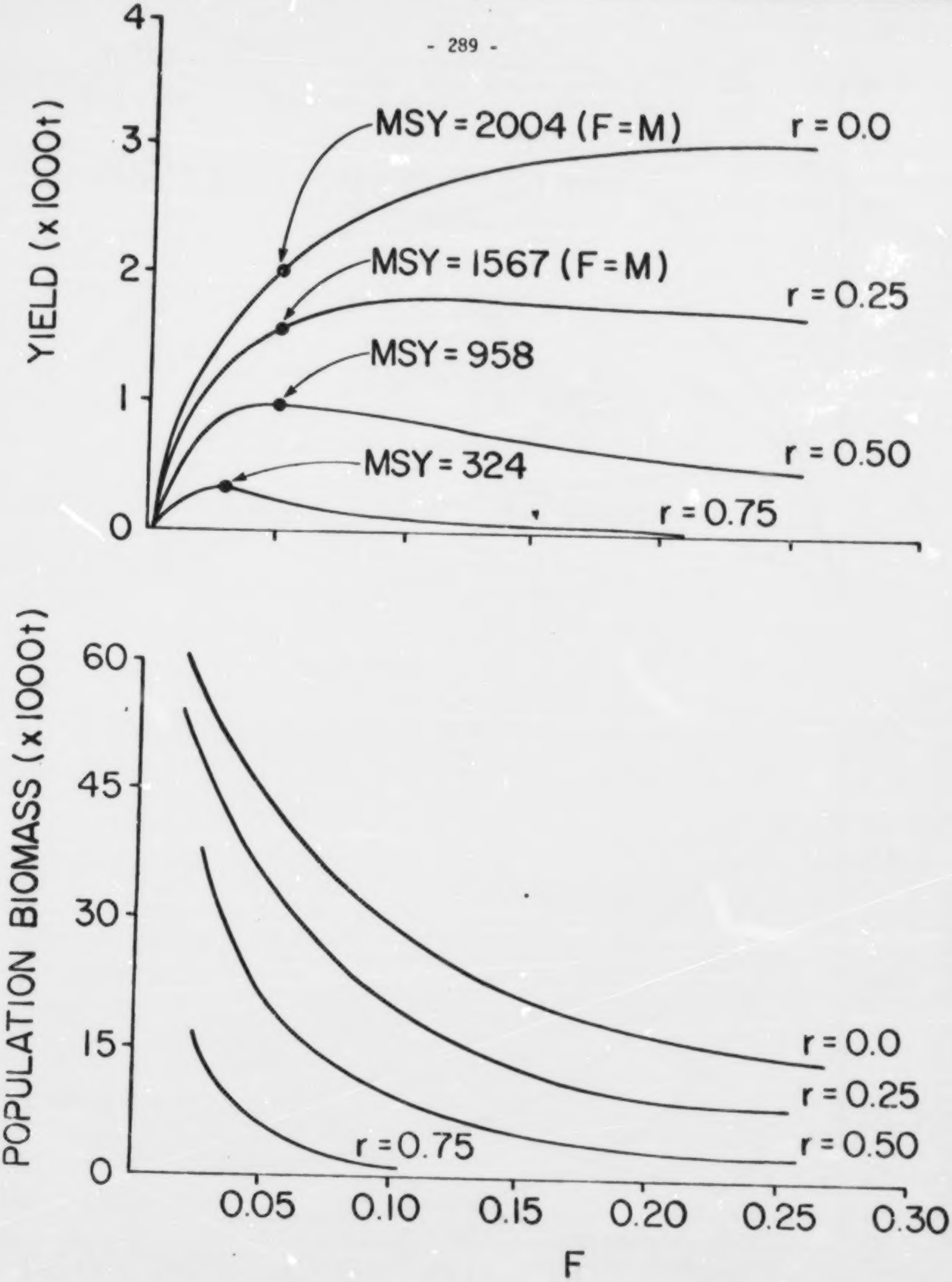
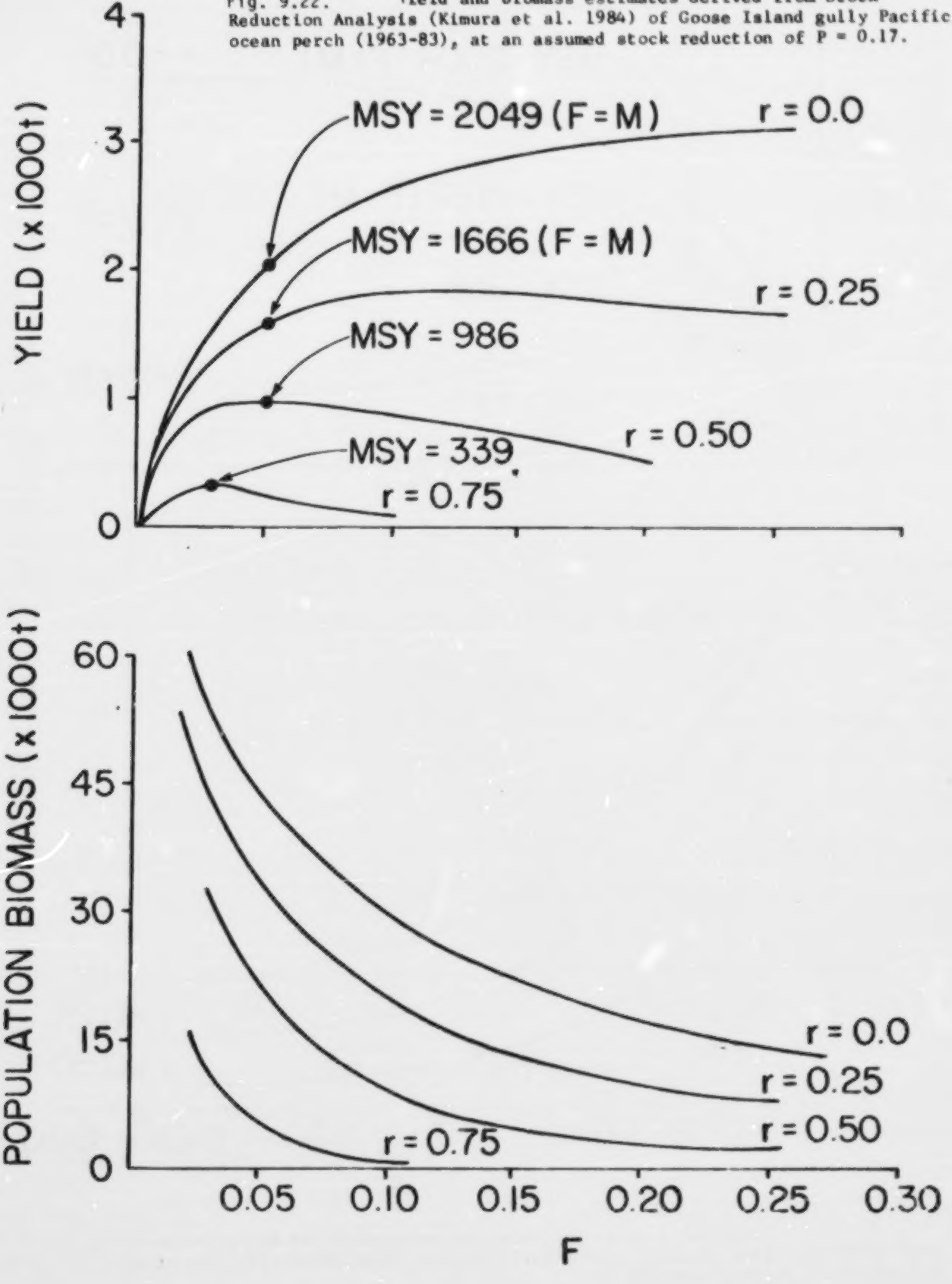


Fig. 9.21. Yield and biomass estimates derived from Stock Reduction Analysis (Kimura et al. 1984) of Goose Island gully Pacific ocean perch (1963-83) at an assumed stock reduction of P=0.15.

Fig. 9.22. Yield and biomass estimates derived from Stock Reduction Analysis (Kimura et al. 1984) of Goose Island gully Pacific ocean perch (1963-83), at an assumed stock reduction of P = 0.17.



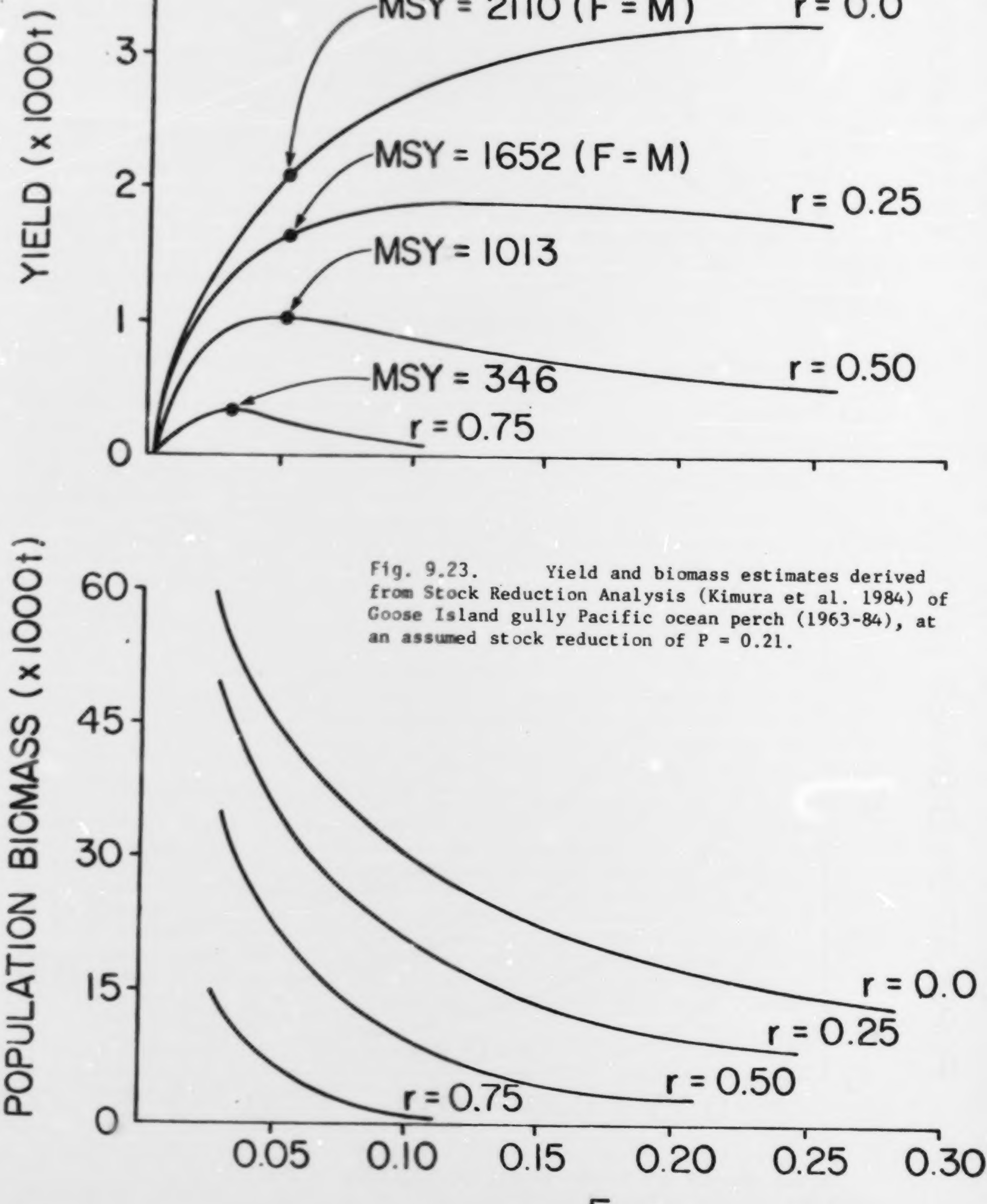


Fig. 9.23. Yield and biomass estimates derived from Stock Reduction Analysis (Kimura et al. 1984) of Goose Island gully Pacific ocean perch (1963-84), at an assumed stock reduction of P = 0.21.

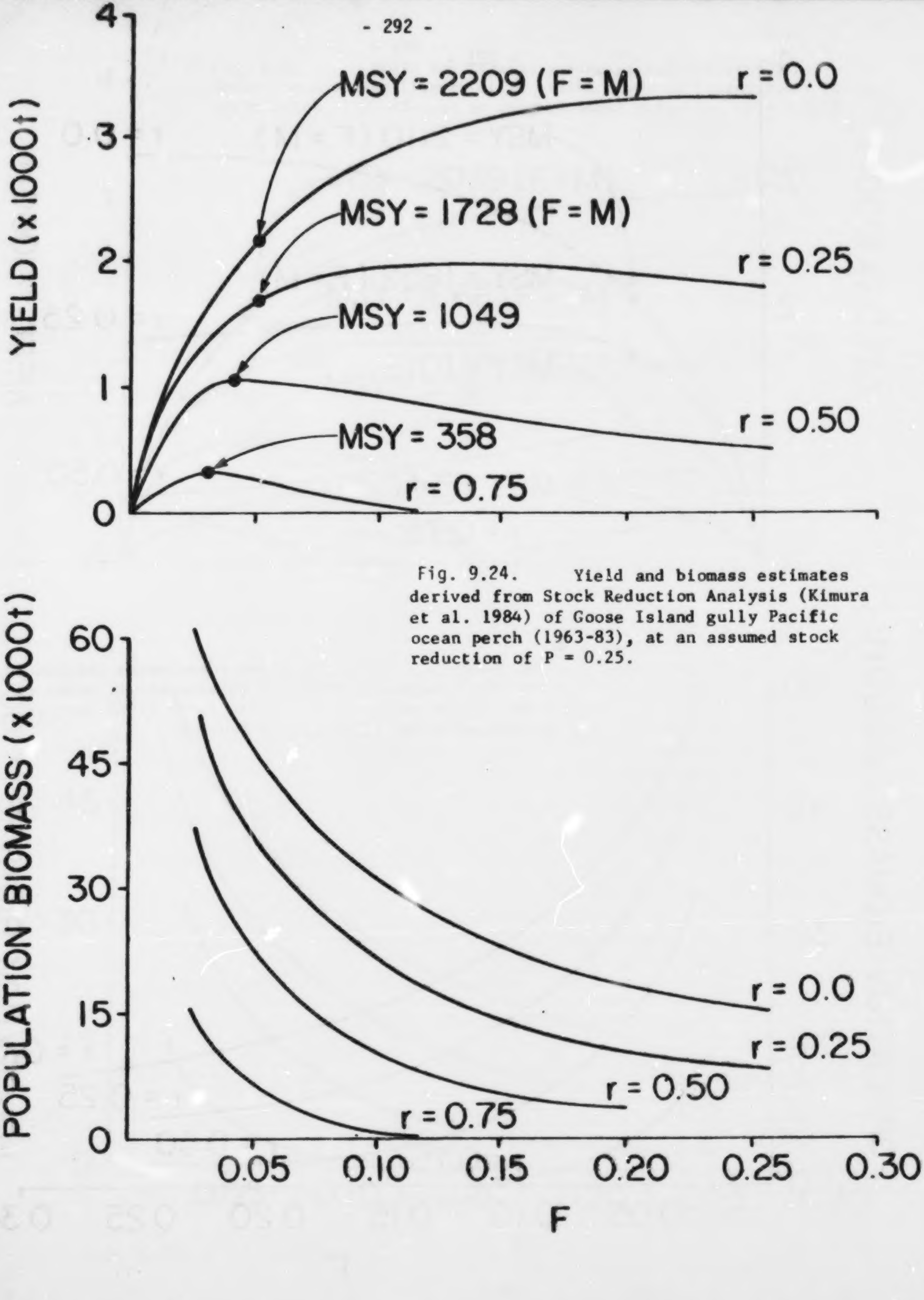


Fig. 9.24. Yield and biomass estimates derived from Stock Reduction Analysis (Kimura et al. 1984) of Goose Island gully Pacific ocean perch (1963-83), at an assumed stock reduction of P = 0.25.

9.1.4. Queen Charlotte Sound (continued)

B. Yellowmouth rockfish (S. reedi)

(i) Landing statistics

The fishery for S. reedi in QCSd is a relatively minor one and landings have only once exceeded 350 t. Table 9.10. presents statistics of the fishery during the 1971-84 period. Significant landings have been associated only with a directed midwater trawl fishery, except in 1983-84. During the latter period a substantial portion of the annual landings have occurred in concert with the winter fishery for Pacific ocean perch off the mouth of Queen Charlotte Sound.

(ii) Assessment and yield options

No analytic assessments of the QCSd S. reedi stock have been made. As noted in previous assessments (Westrheim 1980) the major historical removals of this stock were considered to have occurred in the Japanese fishery and to have averaged over 1800 t/yr in the 1971-77 period, with values as high as 2700 t/yr. Decreases in LPUE for the traditional directed fishery over time suggest that this level of yield was not sustainable, at least from the present biomass. It is difficult to interpret the statistics of the winter fishery since little is known of S. reedi seasonal movements. Summer research work off the mouth of QCSd during 1983-1984 indicated a somewhat lower proportion of S. reedi in S. alutus catches compared with that in the winter fishery (30% vs 40-45%). It is not known whether the concentrated body of S. reedi noted west and south of Triangle Island during the summer months includes those fish observed off the mouth of QCSd during the winter.

Only a single biomass estimate (hydroacoustic) for this stock is available. During October 1978 a biomass of 2000 t was estimated for this stock off Triangle Island. This estimate is believed to be conservative due to the difficulty of accurately estimating the near-bottom component of the stock with hydroacoustic equipment, however the magnitude of this underestimate is unknown. The yield options of Table 9.4. therefore treat the 2000 t as a minimum biomass estimate and the yield from it (200 t) as a conservative figure. The incremental changes to sustainable (350 t) and non-sustainable (500 t) yields reflect the magnitude of such proportional increments for other stocks, where analyses are more detailed, and our uncertainty in estimating biomass of this stock. We do not believe this stock to be as overexploited as the GIG S. alutus stock, however there is evidence of longer exploitation than either the MOR S. alutus or the west Queen Charlottes S. reedi stocks. We therefore assume the sustainable yield from this stock should be at least 150% of our conservative yield estimate. Additional survey work might decrease the uncertainty of these estimates.

9.1.5. Hecate Strait

A. Pacific ocean perch (S. alutus)

(i) Landing statistics

Table 9.11. details exploitation statistics of the Moresby gully (MOR) stock of Pacific ocean perch. The statistics presented are for our best

Table 9.10. Yellowmouth rockfish (S. reedi) interviewed and total landings (t), effort (h) and LPUE (t/h) in Goose Island and Mitchell's gullies.

Year	Total landings	Interviewed					
		0% qualification			25% qualification[a]		
		L	E	LPUE	L	E	LPUE
1971	5.35	5.35	31.5	.170	-	-	-
1972	-	-	-	-	-	-	-
1973	176.65	176.65	37.0	4.774	176.21	32.5	5.422
1974	78.91	78.91	23.0	3.431	78.91	23.0	3.431
1975	1.08	1.08	34.5	.031	-	-	-
1976	12.29	12.29	10.0	1.229	12.29	10.0	1.229
1977	335.89	335.89	466.0	.721	331.29	226.3	1.464
1978	16.54	16.54	110.0	.150	10.86	16.0	.679
1979	10.25	10.25	102.0	.101	6.49	9.7	.669
1980	27.92	27.92	97.5	.286	24.77	32.7	.758
1981	4.74	4.74	25.6	.185	.07	2.0	.033
1982	191.86	176.94	167.5	1.056	163.42	39.8	4.111
1983	528.64	455.57	492.2	.926	367.12	151.4	2.424
1984*	342.41	85.74	262.1	.327	68.73	128.5	.535

*To July 20, 1984.

[a] At least 25% of landing must be S. reedi for inclusion of data.

understanding of the boundaries of the MOR stock and include landings from some sections of Area 5B as well as Area 5C. A 2000 t quota has been in effect for this stock since 1982, however withholding of logbook information by some vessel masters contributes some uncertainty in the allocation of landings to this stock unit.

LPUE for the MOR stock has risen in the last three years, although LPUE for the first opening of 1984 was down from 1983.

(ii) Stock assessment and yield options

Assessment of the MOR stock is based primarily upon biomass surveys conducted in 1974, 1978, and 1981. Table 9.12. presents the biomass estimates obtained during these surveys and their modifications. The most recent estimate for this stock is 35,500 t, assuming a catching coefficient of 1.0 for the area swept between the trawl doors. The decrease in the 1981 estimate from its original value is accounted for by the application of improved estimators for the calculation of door spread (Carrothers 1980) over the simple triangulation formulae first used.

The age spectrum of this stock in the landings is extensive (5-72 y) and the short exploitation history precludes any age-structured analysis. It is believed that this stock experienced little or no exploitation prior to 1980 and if so, a rare opportunity to examine stock dynamics at high biomass levels exists. It is imperative from a scientific management view, to determine the response of this stock to exploitation at the level of fishing mortality associated with maximum long-term yield. From the detailed analysis of the GIG stock, this should occur at approximately F = 0.06 and that yield (2000 t) is identified as the sustainable yield in Table 9.4. Yields associated with other options (conservative = 1700 t, non-sustainable = 2500 t) have also been calculated on the basis of the GIG analysis. We anticipate that sustainable yield for this stock will continue to be identified with a level of F approximately equal to M for at least a decade, to permit evaluation of such a harvest strategy. Increasing exploitation prior to that period will obscure our only opportunity to conduct such an evaluation.

B. Yellowmouth rockfish--*S. reedi*

(i) Landing statistics

Yellowmouth rockfish has had a relatively short exploitation history in the Moresby gully area and only in the past three years have landings exceeded 100 t (Table 9.13.). It is also apparent from this table that the majority of landings are incidental to those of other species (generally *S. alutus*), indicated by the low proportion of total landings included in the qualified landings.

(ii) Assessment and yield options

No analytic studies of *S. reedi* in MOR have been conducted. The paucity of both statistical and biological data for this area precludes any quantitative analysis. The incidental nature of the fishery suggests limited opportunity for control of the harvest. It is unlikely that a directed

Table 9.11. Pacific ocean perch interviewed landings, effort, and LPUE t/h from Moresby Gully.

	Interviewed			
Year	Landings (t)	Effort (hr)	LPUE (t/h)	Total landings
1966	-	-	-	0.33
1967	-	-	-	-
1968	-	-	-	-
1969	-	-	-	-
1970	-	-	-	-
1971	2	10	0.200	1.50
1972	-	-	-	-
1973	-	-	-	-
1974	10.12	11.3	.896	10.12
1975	93.64	91.3	1.026	96.75
1976	39.67	109.0	.364	43.40
1977	3.71	8.5	.436	41.13
1978	162.30	155.3	1.045	162.30
1979	223.83	215.9	1.037	225.35
1980	2145.76	1540.4	1.393	2432.59
1981	1479.57	1019.5	1.451	2166.30
1982	2711.59	1346.0	2.015	3561.99
1983	1491.27	641.4	2.325	2204.22
1984*	779.69	366.6	2.127	1465.00

*To July 20, 1984.

Table 9.12. Biomass estimates of Pacific ocean perch in Moresby gully.

Year	Biomass (t)	Data source	Notes
1974	136,079	Westrheim et al. 1974	-
	72,900	Harling and Davenport 1977	1
	20,514	Harling and Davenport 1977	2
	16,461	Harling and Davenport 1977	3
1978	77,000	Harling et al. 1979	-
	21,668	Harling et al. 1979	2
	17,387	Harling et al. 1979	3
1981	44,400	Carter et al. 1982	4
	35,520	Carter et al. 1982	5

NOTES:

1. Harling et al. (1978) reported a revised swept area for the trawl net used in the 1974 survey based on a new estimate of the distance between the wings. Original estimate was 29 ft; revised estimate was 50 ft. Harling and Davenport (1977) indicated trawl survey work conducted during 1976 as the source for the revised estimate but this is in error. No net mensuration work was conducted during 1976 and the estimate may have been derived from information on sweepline effects collected in 1977 (Harling and Davenport 1977), although no supporting documentaion for the estimate exists. Towing speed also changed from 3.0 to 3.25 kt (correction factor = 0.53575).

2. The revised estimates are derived from applying a correction factor of 0.2814 to account for the area swept between the trawl doors rather than the wing tips of the net. Distance between the doors calculated by triangulation of net measurements.

3. Revised estimates based on application of the correct line and net catenaries, the angle of incidence of the two catenaries and the door offset calculation (Carrothers 1980). This results in a correction factor of 0.2258.

4. Survey not strictly comparable to previous surveys due to minor differences in area coverage and different fishing gear.

5. As (3) but for the net used in this survey the correlation factor is 0.8.

fishery by all vessels is even possible for S. reedi in this area, given the unavoidable incidence of S. alutus that would occur in such a fishery. The foregoing suggests that grouped management of the two species is the most viable strategy. Table 9.4. presents this option for S. reedi, yields being assessed through the proportional incidence of S. reedi in the S. alutus fishery (1980-84 average = 0.1217) applied to the yield options identified for S. alutus. Conservative, sustainable and non-sustainable yield options are thus 200 t, 240 t and 300 t, respectively.

9.1.6. West coast Queen Charlotte Islands

Area 5E has been divided into two exploitation areas (north and south of 54°N) based on historical performance of the domestic fishery and the areas of operation of the major foreign fisheries from 1965-77. Additionally, because of the coincident nature of slope rockfish catches in this area, they are grouped in the following sections.

A. All Species (south of 54°N)

(i) Landing statistics--5E (south of 54°N)

Tables 9.14.-9.16. present statistics of the fisheries for S. alutus, S. reedi and S. aleutianus, south of 54°N. These species have been managed as a group since 1983. An inverse relationship between the unqualified LPUE for S. alutus and S. reedi is evident over the 1980-84 period, however this relationship is not evident in the qualified (25%) statistics. The landing statistics for S. reedi also exhibit a downward trend in qualified LPUE, but the amount of effort involved is small.

As in the case of Area 5C, there is some uncertainty to the assignment of landings to this area during 1984, due to withholding of logbook information by some vessel masters.

(ii) Assessment

Assessment of the three species in this area has been based on biomass surveys during 1978 and 1979 (Leaman and Nagtegaal 1982) and regressions of fishery statistics (in Stocker 1981). The biomass estimates

Table 9.13. *Sebastes reedi* interviewed and total landings (t), effort (h), and LPUE (t/h) in Moresby Gully.

Area 3D							
		Interviewed					
	Total	0% qualification			25% qualification[a]		
Year	landings	L	E	LPUE	L	E	LPUE
1978	91.94	91.94	54.3	1.693	84.65	45.2	1.873
1979	20.48	20.48	37.6	.545	-	-	-
1980	20.13	20.13	28.7	.702	1.50	5.5	.272
1981	109.67	40.95	116.6	.351	-	-	-
1982	417.32	325.15	711.6	.457	228.75	202.1	1.132
1983	202.04	78.24	329.7	.237	15.22	39.8	.383
1984*	195.72	71.44	110.4	.647	35.24	50.2	.702

*To July 20, 1984.

[a] At least 25% of landing must be *S. reedi* for inclusion of data.

Table 9.14. Canadian landings (t), effort (h), and LPUE (t/h) of S. alutus, from Area 5E, south of 54°.

		Area 5E					
		Interviewed					
		0% qualification			25% qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1976	78.78	78.78	59.0	1.335	78.78	59.0	1.335
1977	1549.42	1475.24	1041.5	1.416	1321.29	651.4	2.028
1978	2413.70	2346.93	1043.9	2.248	2255.89	724.4	3.114
1979	839.28	839.28	557.4	1.506	823.09	376.1	2.188
1980	876.96	472.90	496.2	0.953	449.31	332.5	1.351
1981	599.21	432.73	235.7	1.836	412.99	172.5	2.394
1982	614.11	606.73	443.1	1.369	550.38	308.8	1.782
1983	835.17	762.67	629.8	1.211	721.46	403.8	1.787
1984*	453.75	260.42	234.9	1.109	237.86	107.9	2.204

*To July 20, 1984.

[a] At least 25% of landing must be S. alutus for inclusion of data.

Table 9.15. Canadian landings (t), effort (h), and LPUE (t/h) of *S. reedi*, from Area 5E, south of 54°.

Area 5E south							
		Interviewed					
		0% qualification			25% qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
1977	1256.74	1256.74	583.0	2.156	1226.64	438.2	2.799
1978	1104.64	1104.64	600.4	1.840	858.89	296.3	2.899
1979	388.54	388.54	356.5	1.090	328.72	204.7	1.606
1980	499.91	477.23	321.5	1.484	477.23	321.5	1.484
1981	922.41	380.12	192.2	1.978	350.89	129.9	2.701
1982	414.39	351.87	335.9	1.048	307.98	191.9	1.605
1983	588.21	556.22	575.5	0.966	501.10	356.7	1.405
1984*	365.50	161.98	252.1	0.643	142.29	140.3	1.014

*To July 20, 1984.

[a] At least 25% of landing must be *S. reedi* for inclusion of data.

Table 9.16. Canadian landings (t), effort (h), and LPUE (t/h) of rougheye rockfish (S. aleutianus) from Area 5E, south of 54°.

Area 5E south							
		Interviewed					
		0% qualification			25% qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
1977	76.28	76.28	134.5	0.567	[illegible]4.69	66.0	1.132
1978	139.49	139.49	396.9	0.351	105.17	118.3	0.889
1979	192.09	192.09	347.7	0.552	159.51	137.1	1.163
1980	51.42	51.42	60.0	0.857	50.31	23.0	2.187
1981	9.93	9.93	46.2	0.215	5.13	7.2	0.713
1982	274.38	274.38	269.3	1.019	262.55	156.2	1.681
1983	74.16	61.37	324.1	0.189	26.70	22.0	1.214
1984*	91.28	67.19	180.9	0.371	19.49	22.2	0.878

*To July 20, 1984.

[a] At least 25% of landing must be S. aleutianus for inclusion of data.

from these two reports suggested a 1980 biomass in the range 11,300-25,300 t for all rockfishes, of which S. alutus, S. reedi and S. aleutianus constitute approximately 60-65% over the total area. The biomass estimates from the surveys are viewed as slightly conservative due to inadequate coverage of one area.

During 1983-84 we supplied data and advice to investigators who were attempting to use search theory and detailed fishing statistics to estimate stock size for aggregated species, with limited time-series of data. The report of this project is contained in Mangel and Beder (1984). Briefly, they use conditional probability distributions based on discrete schools, time spent fishing catches and some a priori assumptions of encounter probabilities to predict the present distributions giving rise to the observed catches from known effort. Applying this theory to the Rennell Sound S. alutus data suggested a 1977 biomass of 14,200-21,900 t. The theory involves a number of strong assumptions concerning school size and depletion, and will require more extensive development. Nonetheless, the estimates produced are of the same general magnitude as those from other techniques. The authors suggest that improved estimates of model parameters will result in lowered total biomass estimates.

The statistics of the fishery involving S. reedi in the area are cause for concern. It is difficult to determine the cause for the recent decline in LPUE although several factors may contribute. Firstly, the fishery in recent years has not achieved the desired species contributions to grouped quotas due to ineffective enforcement of time/area closures. This resulted in truncation of the fishing seasons with the effect that little fishing occurred in the fall, when catch rates for S. reedi are generally higher. Secondly, the LPUE for 1981 is somewhat anomalous with the adjacent values; a cause for which may be the low percentage of the total catch covered by interview. Lastly, the 1984 statistic does not include the full calendar year and is subject to change.

(iii) Yield options

No changes in the individual species yield options from the 1984 assessments are recommended (Table 9.4.). However, if management opts for a continuation of assemblage management for this area, a shift in the periods of opening is suggested in an attempt to optimize the S. reedi contribution to the total catch. This shift is based upon a review of monthly landing statistics over the period 1977-83, and suggests a closed period from July-August.

B. All species (north of 54°N)

(i) Landing statistics

Major foreign exploitation of this area has been detailed in previous assessment reports (Ketchen 1980a; Westrheim 1980). Tables 9.17.-9.19. provide such data for the domestic fishery, 1976-84. LPUE of the fishery has been erratic for all species. Withholding of logbook information and/or lack of interview coverage of landings has been a significant negative factor in the documentation of this fishery.

The large increase in landings during 1984 is the result of a removal of fishing restrictions, for experimental purposes.

Table 9.17. Canadian landings (t), effort (h), and LPUE (t/h) of S. alutus, from Area 5E, north of 54°.

Area 5E north							
		Interviewed					
		0% qualification			25% qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
1977	1.42	1.42	19.7	0.072	0.7	2.3	0.304
1978	22.22	22.22	151.1	0.147	6.65	16.8	0.396
1979	227.49	227.49	177.5	1.282	223.83	108.5	2.063
1980	84.56	84.56	119.3	0.709	64.80	39.5	1.641
1981	109.22	63.58	32.4	1.962	53.15	24.1	2.205
1982	342.23	218.48	144.1	1.516	194.18	109.3	1.777
1983	291.98	226.43	401.8	0.564	208.28	193.5	1.076
1984*	1788.06	1470.31	901.5	1.631	1436.01	684.1	2.099

*To July 20, 1984.

[a] At least 25% of landing must be S. alutus for inclusion of data.

Table 9.18. Canadian landings (t), effort (h), and LPUE (t/h) of *S. reedi* from Area 5E, north of 54°.

Area 5E north							
		Interviewed					
		0% qualification			25% qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
1979	16.86	16.86	69.9	0.241	4.08	4.1	0.995
1980	-	-	-	-	-	-	-
1981	2.34	2.34	4.9	0.478	2.34	4.9	0.478
1982	67.88	54.58	70.3	0.776	52.36	36.5	1.435
1983	52.23	18.36	44.5	0.413	3.48	9.0	0.387
1984*	73.23	63.44	468.3	0.135	15.79	14.9	1.061

*To July 20, 1984.

[a] At least 25% of landing must be *S. reedi* for inclusion of data.

Table 9.19. Canadian landings (t), effort (h), and LPUE (t/h) of *S. aleutianus* from Area 5E, north of 54°.

		Area 5E north					
		Interviewed					
		0% qualification			25% qualification[a]		
Year	Total landings	L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
1979	13.99	13.99	139.5	0.100	9.73	64.1	0.152
1980	2.58	2.58	42.5	0.061	-	-	-
1981	98.08	98.08	26.0	3.772	94.20	23.0	4.100
1982	69.09	69.09	74.4	0.929	65.66	34.8	1.887
1983	127.46	84.01	271.5	0.309	43.39	44.3	0.979
1984*	188.57	170.22	587.9	0.290	82.74	115.3	0.718

*To July 20, 1984.

[a] At least 25% of landing must be *S. aleutianus* for inclusion of data.

(ii) Assessment

The primary tool for assessment of rockfishes in this area has been trawl survey. The 1979 survey indicated a biomass of ~2,800 t of *S. alutus*. While complete results of the 1983 survey are not available, distribution and abundance of fish in the area were apparently similar to 1979.

In 1984 it was recommended that the harvest restrictions in this area be removed, on an experimental basis, in order to obtain more information on the recruitment process in rockfish stocks at low levels of abundance. This was primarily intended to determine whether the evidently weak stock-recruitment relationship for *S. alutus* might be more manifest below some threshold level of stock abundance. The 1983 survey in the area examined the broad distribution of the stock and collected biological data so that potential immigration/emigration effects could be interpreted. Such an experiment requires full cooperation from the fishing fleet so that landings may be correctly assigned to stock units. Without this information such an experiment will fail. The 1984 fishery did not yield such cooperation and we cannot endorse continuation of this experiment.

(ii) Yield options

The 1984 fishery is believed to have further reduced the existing low level of biomass for rockfishes, north of 54°. Considerably greater yield from these stocks could be realized if they could be rehabilitated. Yield options of Table 9.4. are derived from biomass estimates and subsequent fishery results. The conservative yields are identified as zero tonnes for all species; sustainable yields are those arising from non-directed fishing only; while non-sustainable yields are 200 t and 250 t for *S. alutus* and *S. aleutianus* separately, or 450 t in total.

9.2. Shelf rockfish (silvergray, yellowtail, canary rockfish)

by R. Stanley

General

The various shelf rockfish species which populate the continental shelf of British Columbia have been exploited by trawlers since the mid-1960s. The principal species have been Sebastes brevispinis (silvergrey rockfish), S. flavidus (yellowtail rockfish) and S. pinniger (canary rockfish). S. paucispinis (Bocaccio) and S. entomelas (widow rockfish) are normally caught incidentally with other species but can attain significant landings.

Shelf rockfishes like the slope forms are characterized by slow growth (K = 0.05-0.15), high age at first capture (6-10 yr) and at first maturity (9-13 yr), low natural mortality rates (M = 0.03-0.20) and great longevity (40-85 yr). This combination of life history characteristics suggests in general that shelf rockfish are low-volume production systems for which annual yields must be restricted to a small percentage of the standing biomass (Westrheim 1980). More detailed analyses of these species' stock dynamics, however, is hampered by a lack of biological knowledge, the low landings, the ephemeral nature of the fisheries and a shortage of ageing data.

The free-swimming larvae are released in late winter and early spring but virtually no information is available on the juvenile phase until they begin to recruit at age 6 to 10. Ageing studies have been sufficient to characterize growth, life span, and to a limited extent, mortality rates, but have not been continued and therefore are not complete enough to examine recruitment variation or to examine how recent yields have affected stock composition.

Migration patterns of shelf rockfish are poorly known although S. flavidus appears mobile. While recoveries have been low from a tagging experiment (<1% of released fish), over 65% of the recoveries have shown southward migration and over 60% of those have shown movements greater than 200 km. Extreme movements have been from Queen Charlotte Sound to Cape Flattery, Washington, and Cape Flattery, Washington to Coos Bay, Oregon. S. brevispinis and S. pinniger are assumed to be less mobile as adults with a body shape more consistent with a bottom-dwelling existence.

The nature of the fisheries further constrains stock analysis. Catches are generally low; qualified landings (25%) are often lower than 50 twhich precludes LPUE analysis either as simple trend analysis or in the form of a surplus production model.

Catch-at-age analysis is not possible since for most of the shelf rockfish stocks only 1 or 2 samples have been aged. De Lury analysis (Ricker 1975) is precluded because most of the stocks have had 15-20 years of exploitation so one cannot ignore recruitment effects.

Finally, because shelf rockfish have traditionally been relatively unimportant, few surveys have been directed at their assessment. Without biomass estimates we cannot use Kimura and Tagart's (1982) stock reduction analysis.

The only information available is that of historical landings levels and a collection of port samples of varying completeness. While most have not been aged, they include length, sex and maturity observations.

We initially attempted to age the samples through length frequency analysis (Breen and Fournier 1984) but the asymptotic growth and longevity of rockfish did not permit any segregation by age-class. A more productive approach for those areas from where we have obtained numerous samples has been to use a length frequency simulator which generates an expected length sample base on a given total mortality rate, von Bertalanffy growth parameters, partial recruitment factors, and the expected variance about these parameters (Breen and Fournier 1984). The growth parameters were taken from Archibald et al. 1981. Estimates of partial recruitment, the variance in mean length at age, and about mean length at age, were derived from the source data of the same report.

In the present report for Areas 3D and 5A plus 5B, we compare the results of actual samples with theoretical results for various mortality rates and from that estimate the total mortality rate that has been experienced by the stock. Where we have few samples, the mortality rates serve as a point estimate of the exploitation history. Where we have collections over a number of years, the rates are examined as a trend. In both cases, we compared the estimate of Z with total landings to see whether historical landings were having a significant impact--a high Z. Typical theoretical curves are shown in Figures 9.25. to 9.30. for S. brevispinis males from Areas 3C and 5A. The process is simply a graphical approach to examining the actual length frequency composition for sign of an excessively small size composition.

We assumed a natural mortality rate (M) of 0.04-0.08 with the exception of female S. pinniger, the mortality rate of which was reputed to be much higher, ranging from 0.11-0.24 (Archibald et al. 1981). We also assumed that the stocks were in equilibrium. Like most analyses, a consistent trend in recruitment is not identifiable and this can lead to incorrect conclusions in our analyses. In this case, a gradual increase in year-class strength would increase the proportion of younger fish which would result in a higher Z be interpreted as excessive removal of older fish. Declining recruitment would similarly be incorrectly interpreted as low exploitation. The caveat is appropriate to most stock analyses that are not calibrated with an independent measure of stock abundance. We have assumed that increased recruitment would not occur as a trend but as definite year-class "spikes" in the length frequency observations.

These analyses are also sensitive to the choice of partial recruitment factors. These could only be crudely determined from the limited number of aged samples.

The basic approach then for the shelf rockfish analysis was to use length frequency samples to estimate the historical total mortality rate (Z). If the size composition is declining in absence of clear recruitment spikes or if the estimated Z for both sexes was consistently above 0.15-0.20, then we assumed that the average harvest observed since 1967 is not sustainable. If these signs were not evident, then the average yield was considered to be a minimum estimate of the sustainable yield. The over-harvest levels were set at 1.5 to 2 times the equilibrium yield depending on the biological characteristics. This reflects our belief that while the equilibrium yield is poorly determined, over-harvest conditions can result from relatively low yields. This assumption is based largely on the performance of other rockfish fisheries (*S. alutus* and *S. entomelas*) in the eastern Pacific and their similarity to shelf rockfish in terms of growth and longevity parameters. It is also assumed that, should a rockfish stock be over-exploited, it will be slow to exhibit the symptoms and slow to rehabilitate once conservative harvesting is imposed.

A summary of the recommended yield options is shown in Table 9.20.

Table 9.20. Shelf rockfish (*S. brevispinis*, *S. flavidus*, *S. pinniger*).

			Harvest strategy		
Area	Species	Option	Conservative/ rebuilding	Equilibrium/sustainable	Non-sustainable
3C	*S. brevispinis*	A	non-directed	100	200
	S. flavidus		n.d.	200 n.d.	a
	S. pinniger		n.d.	200 n.d.	a
	Shelf rockfish	C	n.d.	300 n.d.	a
3D	*S. brevispinis*	A	150	350	700
	S. flavidus		n.d.	100	250
	S. pinniger		250	500	750
	Shelf rockfish	C	250	750	1500
5A+B	*S. brevispinis*	A	400	750	1200
	S. flavidus		500	1500	2500
	S. pinniger		200	500	1000
	Shelf rockfish[b]	B	500	1100	2000
	S. flavidus		500	1500	2500
	Shelf rockfish	C	600	1500(2500)[d]	4000
5C	*S. brevispinis*	A	300	600	1000
	S. flavidus		100	200	400
	S. pinniger		150	250	500
	Shelf rockfish[c]	B	200	450	800
	S. brevispinis		300	600	1000
	Shelf rockfish	C	400	700(1050)[d]	1500

Table 9.20. (cont'd)

			Harvest strategy		
Area	Species	Option	Conservative/ rebuilding	Equilibrium/sustainable	Non-sustainable
5D	*S. brevispinis*	A	combined with Area 5C		
	S. flavidus		150	350	500
	S. pinniger		n.d.	100	200
	Shelf rockfish	C	200	500	750
5E(N)	*S. brevispinus*		100[e]		
	S. flavidus	A	200[e]		
	S. pinniger		200[e]		
	Shelf rockfish	C	200[e] (or free fishing)		
5E(S)	*S. brevispinis*	A	350[e]		
	S. flavidus		200[e]		
	S. pinniger		400[e]		
	Shelf rockfish	C	950[e]		

[a] Joint international quotas recommended if yields exceed suggested equilibrium levels.

[b] *S. brevispinis* and *S. pinniger*.

[c] *S. flavidus* and *S. pinniger*.

[d] Total to be considered if the preliminary landings reflect expected clusters. n.d.=non-directed fishery.

[e] Little knowledge of resource status.

A = single species.

B = partial clustering of selected species considered under A.

C = full clustering of all species.

9.2.1. Coastwide

No coastwide analyses or yield options are discussed for shelf rockfish.

9.2.2. Strait of Georgia

Yield options for shelf rockfish are not proposed for this region.

9.2.3. West Coast Vancouver Island

A. Silvergray rockfish - southern stock

(i) Landing statistics

Canadian landings of *S. brevispinis* in Area 3C have always been small. The 1983 landings of 83 t was the first year Canadian production exceeded 20 t (Table 9.21). U.S. landings have generally been small, with the exception of 1977-1979 when there was a directed fishery in what are now U.S. waters. This fishery has since declined to an average annual landings of 100 t in 1981-82. The absence of a directed fishery and the lack of biological data on the age or length composition preclude any analysis.

The low landings of *S. brevispinis* in spite of the long history of fisheries for this species on grounds to the south and north of Area 3C (Can.) and the history of landings of other rockfish from this area suggest that *S. brevispinis* has never been very abundant.

(ii) Recommendation

The conservative, sustainable and non-sustainable yield options are virtually unchanged from 1984. The conservative, equilibrium, and non-equilibrium options are: a non-directed fishery; 100 t; and 200 t. We recommend that *S. brevispinis* be included as part of a combined shelf rockfish yield.

Table 9.21. Area 3C landings (t), effort (h), and LPUE (t/h) of S. brevispinis, 1967-83.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	0	0	0	-	0	0	-
	USA	48	47	3127	.02	-	-	-
1968	CAN	0	0	0	-	0	0	-
	USA	28	28	1547	.02	-	-	-
1969	CAN	0	0	0	-	0	0	-
	USA	6	6	1475	.00	-	-	-
1970	CAN	2	2	119	.02	1	1	1.00
	USA	21	19	1807	.01	-	-	-
1971	CAN	2	2	2	1.00	2	2	1.00
	USA	57	53	1184	.04	-	-	-
1972	CAN	0	0	0	.00	0	0	-
	USA	7	7	1278	.01	-	-	-
1973	CAN	0	0	0	-	0	0	-
	USA	1	1	1006	.00	-	-	-
1974	CAN	0	0	0	-	0	0	-
	USA	9	8	817	.01	-	-	-
1975	CAN	1	1	35	.03	0	0	-
	USA	38	38	904	.04	-	-	-
1976	CAN	5	5	9	.55	0	0	-
	USA	80	80	2395	.03	-	-	-
1977	CAN	18	18	476	.04	8	5	1.60
	USA	983	983	4390	.22	-	-	-
1978	CAN	1	1	48	.02	0	0	-
	USA	958	958	5319	.18	-	-	-
1979	CAN	1	1	22	.05	0	0	-
	USA	1005	1005	3606	.28	-	-	-
1980	CAN	3	3	20	.10	2	7	.29
	USA	384	384	2514	.15	-	-	-
1981	CAN	0	0	0	-	0	0	-
	USA	148	148	5024	.03	-	-	-
1982	CAN	3	3	224	.01	0	0	-
	USA	60	60	11819	.01	-	-	-
1983	CAN	84	84	156	.54	60	92	.65

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

B. Yellowtail rockfish - southern stock

(i) Landing statistics

The landings history for S. flavidus in Area 3C is shown in Table 9.22. Virtually all of the U.S. landings originated from the U.S. portion of 3C. Canadian production has always been low and has further declined since fishing was restricted to the Canadian portion of 3C. The domestic fishery landed 16 t in 1983 in addition to an estimated 330 t captured as incidental species in the foreign hake fishery.

No age composition data is available for Canadian landings and length frequency information (3 samples in 16 years) is too limited to be of use.

Biomass surveys and stock analyses are summarized in Westrheim (1980) and Tagart (1982). Previous U.S. work has considered all S. flavidus from 3B-3C or 3A-3B-3C as one stock. The U.S. fishery is currently being managed under the assumption that the overall yield for combined Areas 3A, 3B, 3C (U.S.) should be between 1566 t and 2007 t (Tagart 1982).

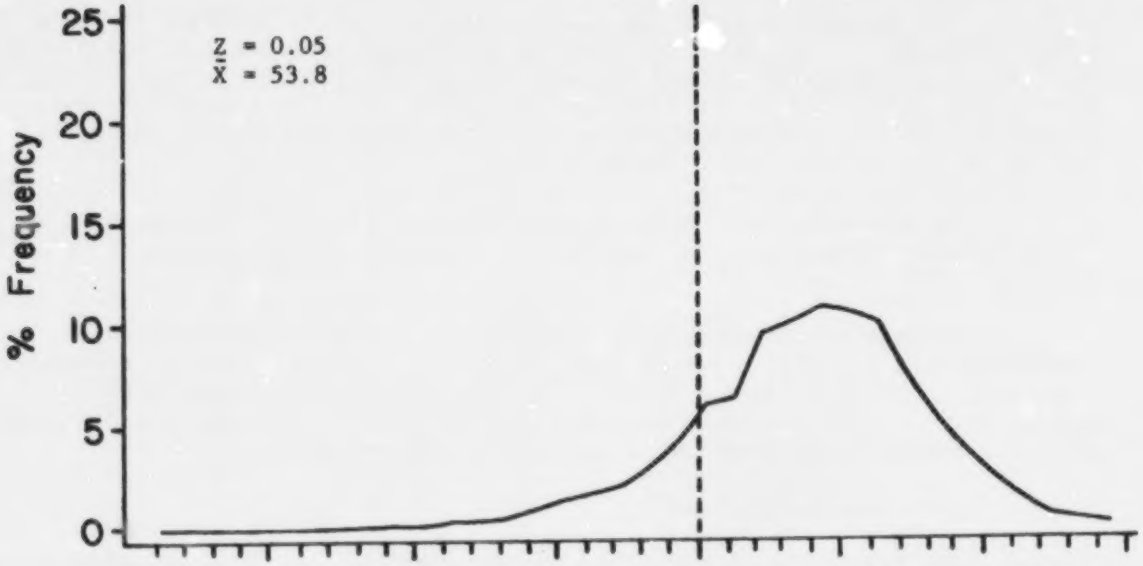
(ii) Recommendations

The limited production from Canadian 3C over the last 18 years strongly suggests that very little of the stock has been available to Canadian trawlers. It may be that the current incidental landings in the hake fishery are removing close to the sustainable yield from this population if it is immobile within Area 3C. A highly conservative yield option would then imply that the domestic fishery be of a non-directed nature.

If yields from this fishery become significant, they must be considered in conjunction with U.S. removals. U.S. biologists have assumed S. flavidus to be a unit stock for all of the Vancouver area and suggest a maximum sustainable yield of between 1500 and 2000 t (Tagart 1982) although this may be revised downwards as they incorporate break-and-burn ageing techniques. As discussed earlier, recent tag returns support the contention that S. flavidus may be one stock through Oregon, Washington and B.C.

If a highly conservative option is not chosen, then it is recommended that discussions be initiated with U.S. authorities about joint management of this stock. In the interim, a directed yield of 200 t might be considered. This yield plus 300 t from the hake fishery far exceeds the traditional Canadian landings from this area without exceeding 33% of the current U.S. perception of the stock's MSY.

Fig. 9.25. Theoretical length distribution of male *S. brevispinis*, Areas 3C and 5A.



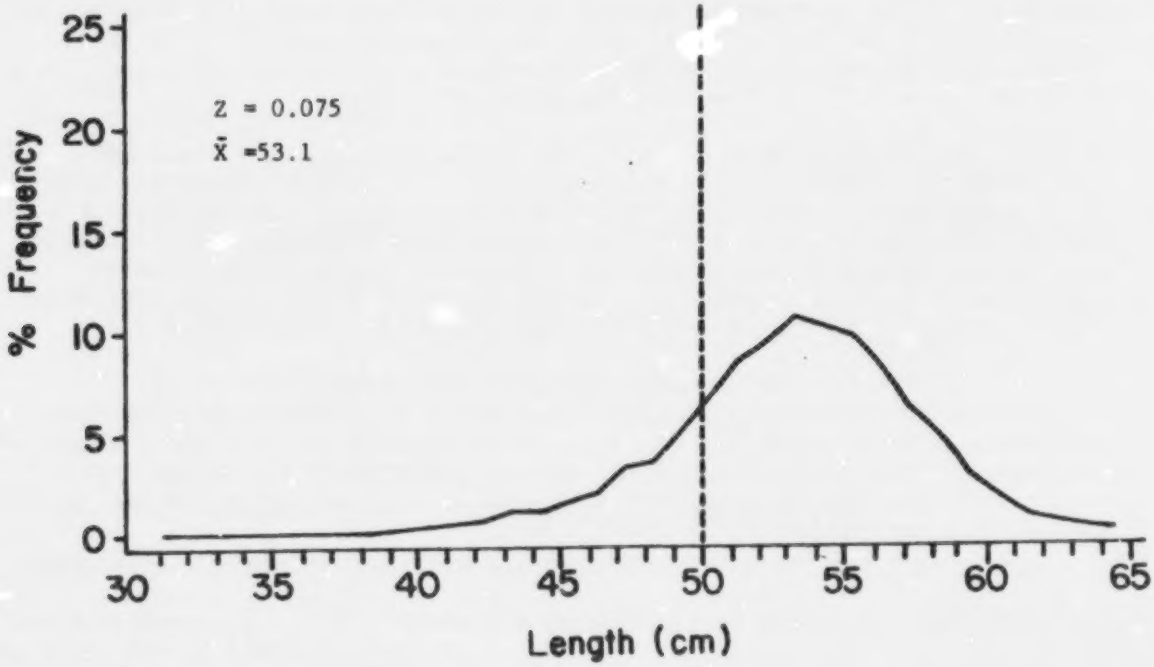
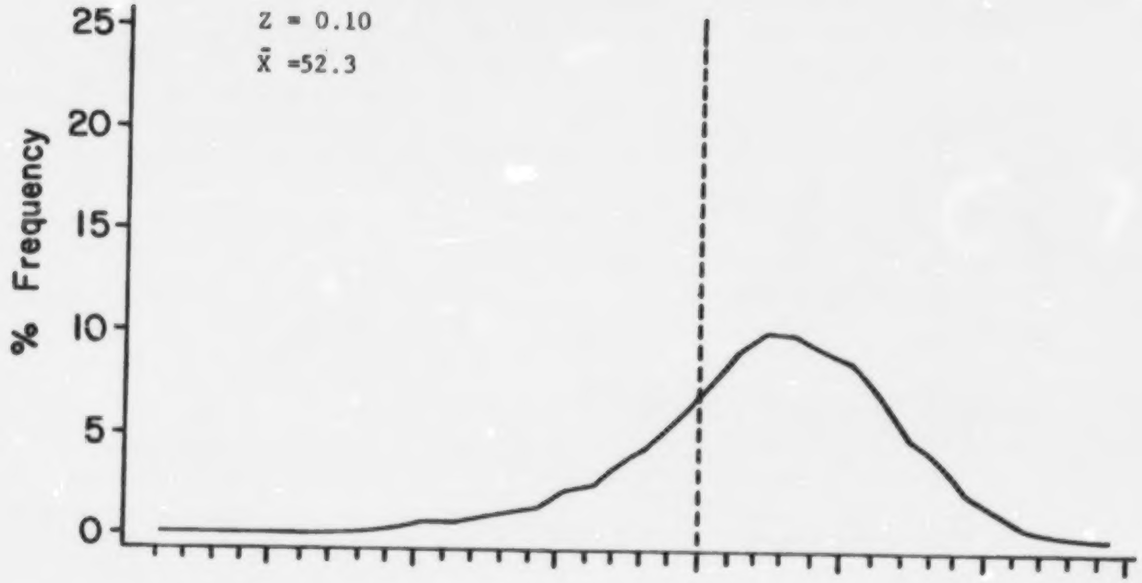


Fig. 9.26. Theoretical length distribution of male *S. brevispinis*, Areas 3C and 5A.

Fig. 9.27. Theoretical length distribution of male S. **brevispinis**, Areas 3C and 5A.



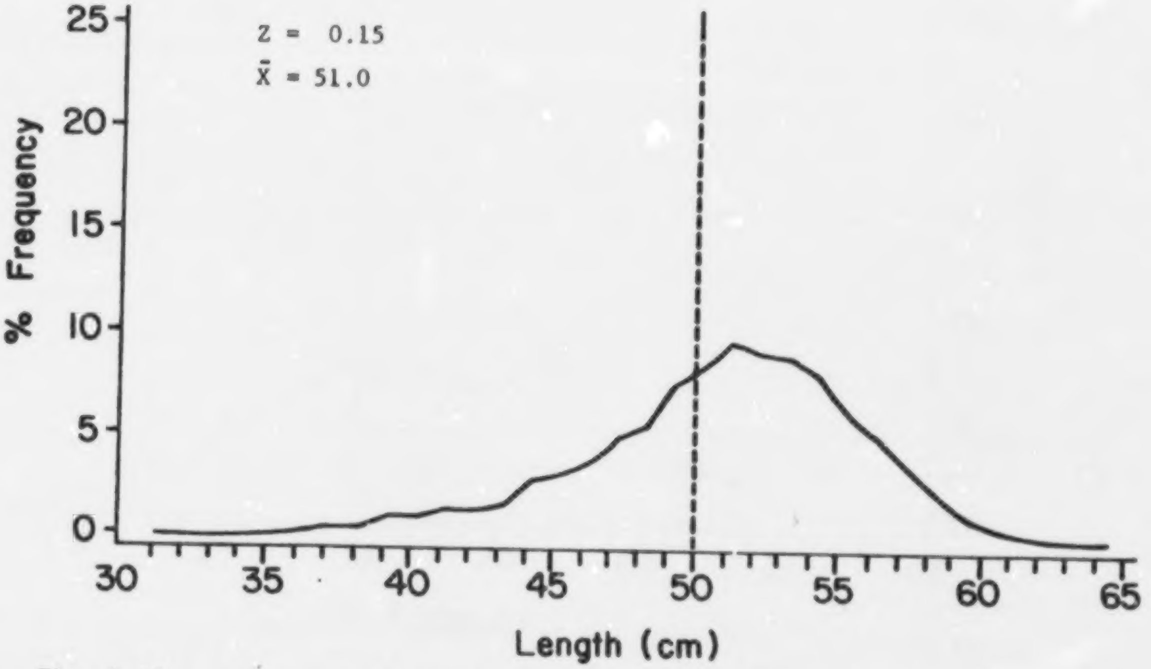
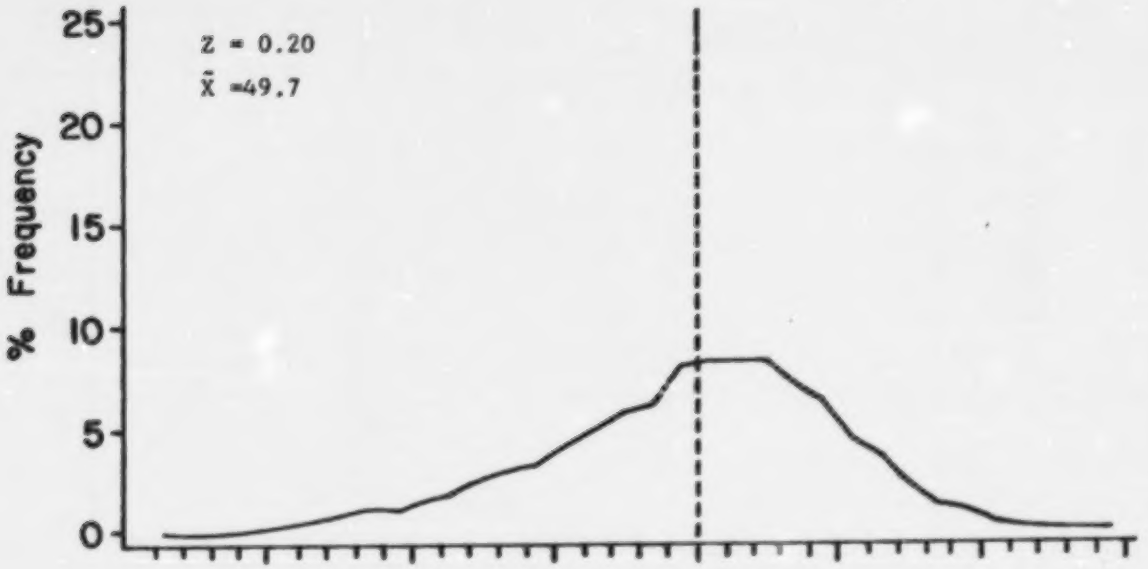


Fig. 9.28. Theoretical length distribution of male S. **brevispinis**, Areas 3C and 5A.

Fig. 9.29. **Theoretical length distribution of male *S. brevispinis*, Areas 3C and 5A.**



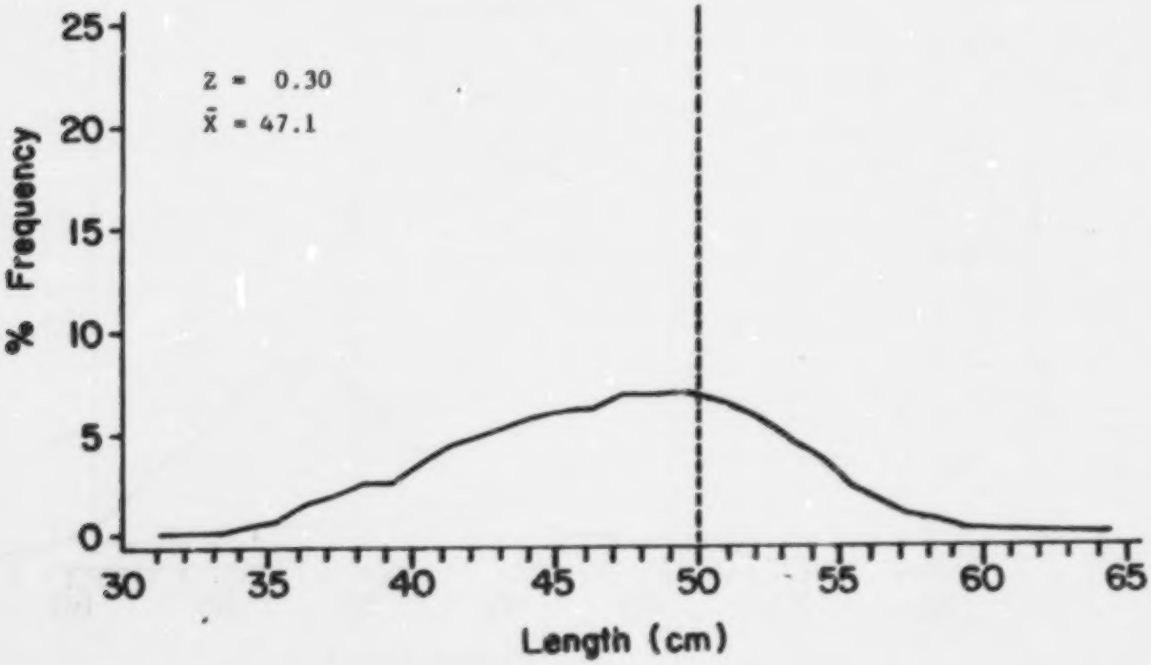
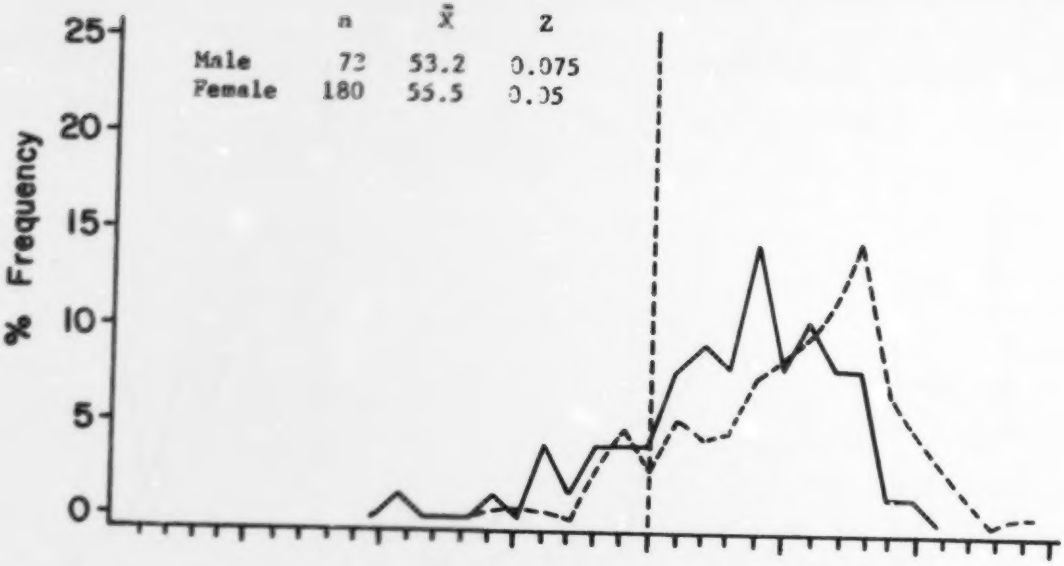


Fig. 9.30. **Theoretical length distribution of male *S. brevispinis*, Areas 3C and 5A.**

Fig. 9.31. Length distribution of *S. brevispinis* for Kain Island, Area 3D, 1982.



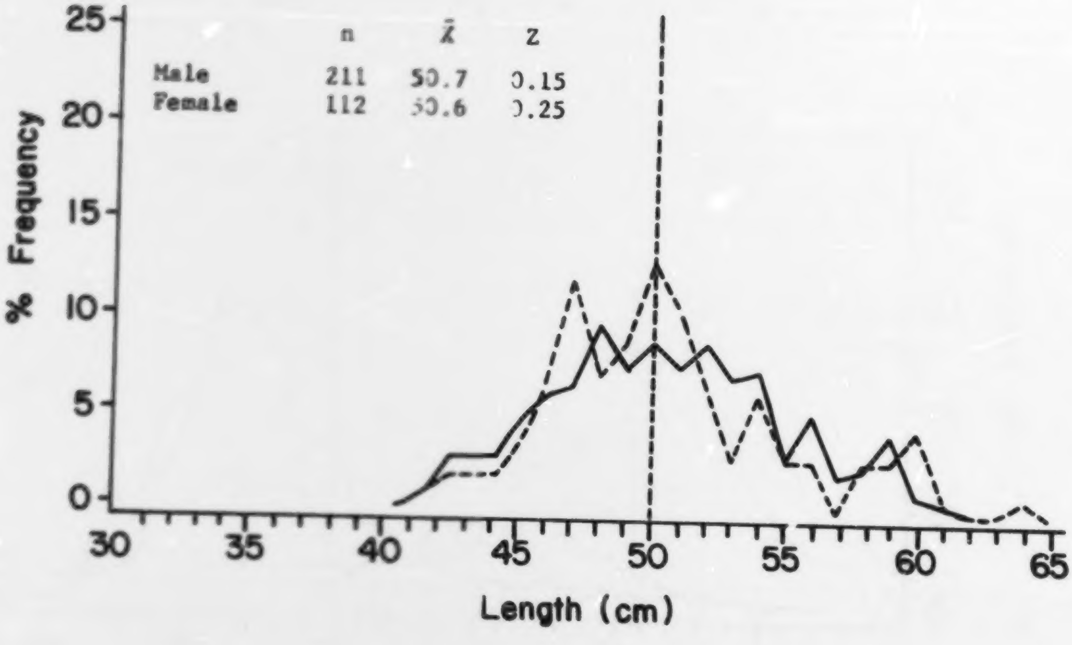
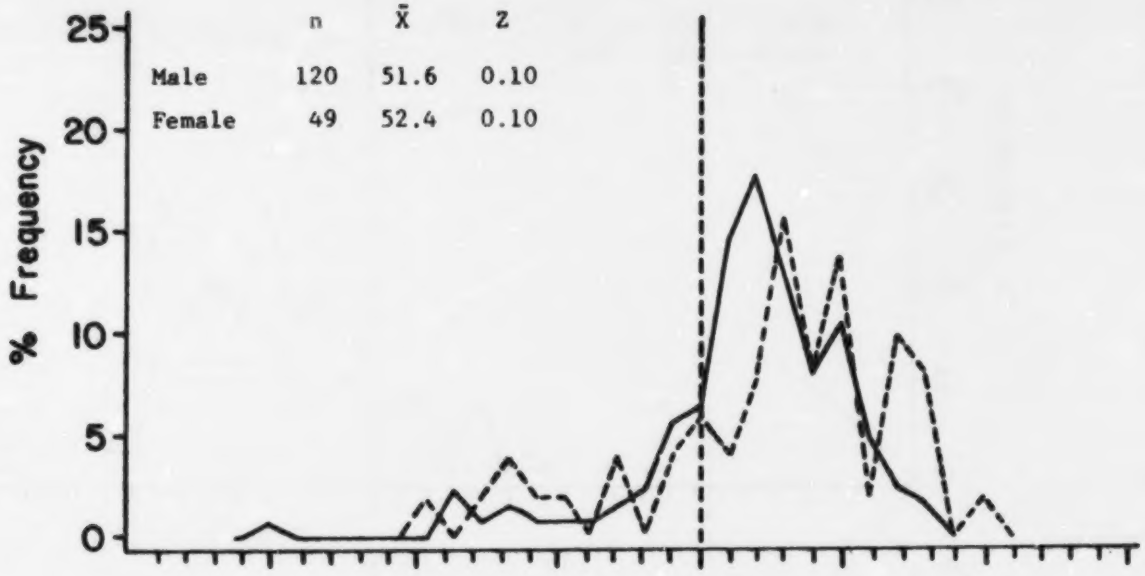


Fig. 9.32. Length distribution of *S. brevispinis* for Nootka Sound, Area 3D, 1983.

Fig. 9.33. Length distribution of S. pinniger for Esperanza, Area 3D, 1976.



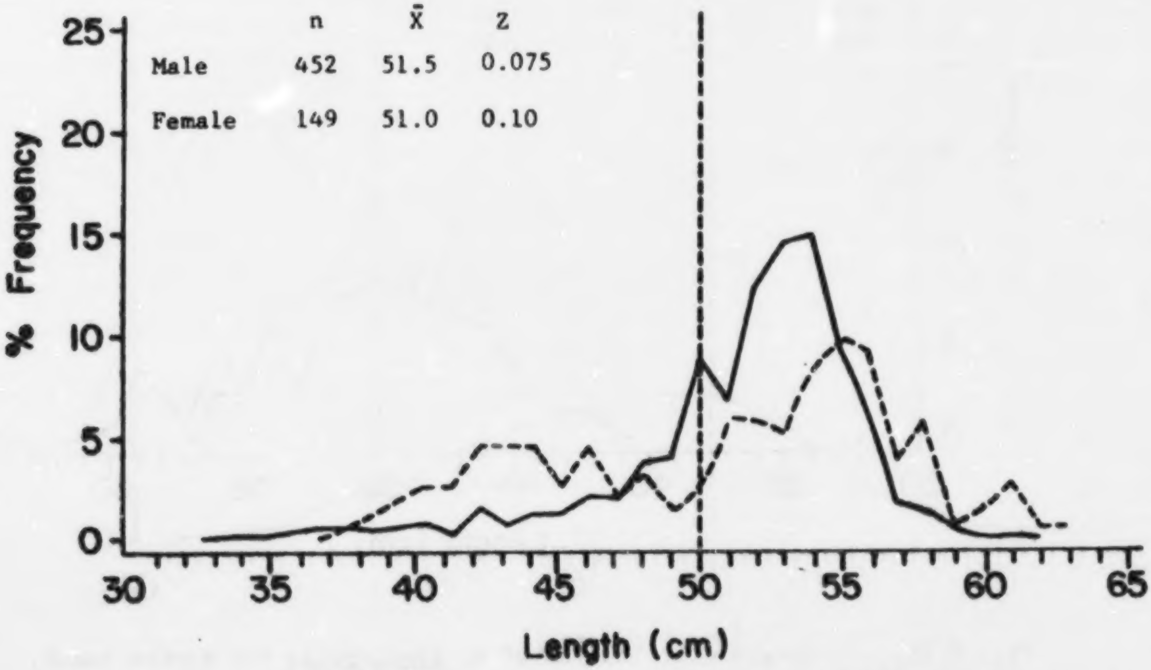
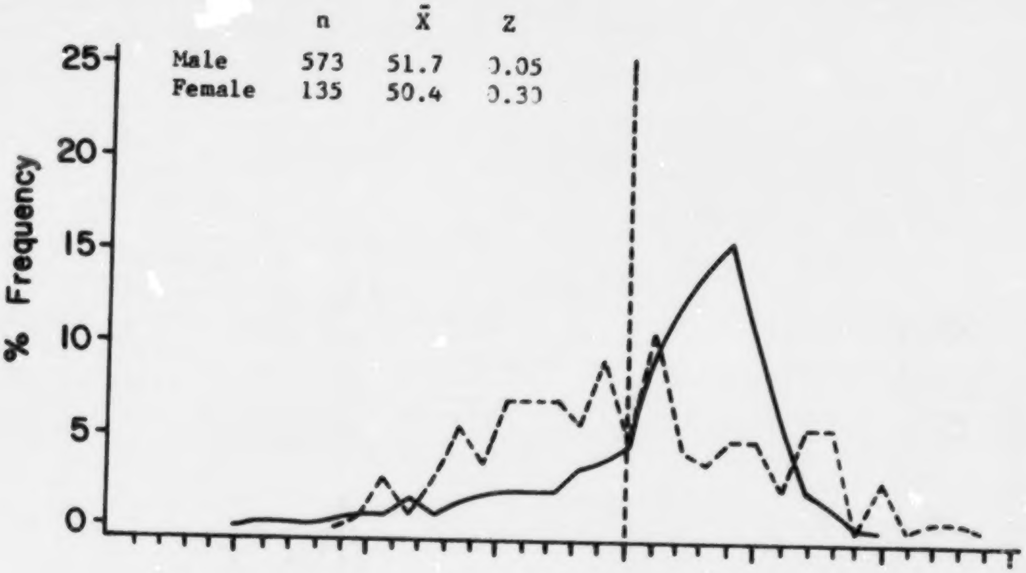


Fig. 9.34. Length distribution of S. pinniger for west Cape Cook, Area 3D, 1977.

Fig. 9.35. Length distribution of S. pinniger from Quatsino and Cape Cook, Area 3D, 1979.



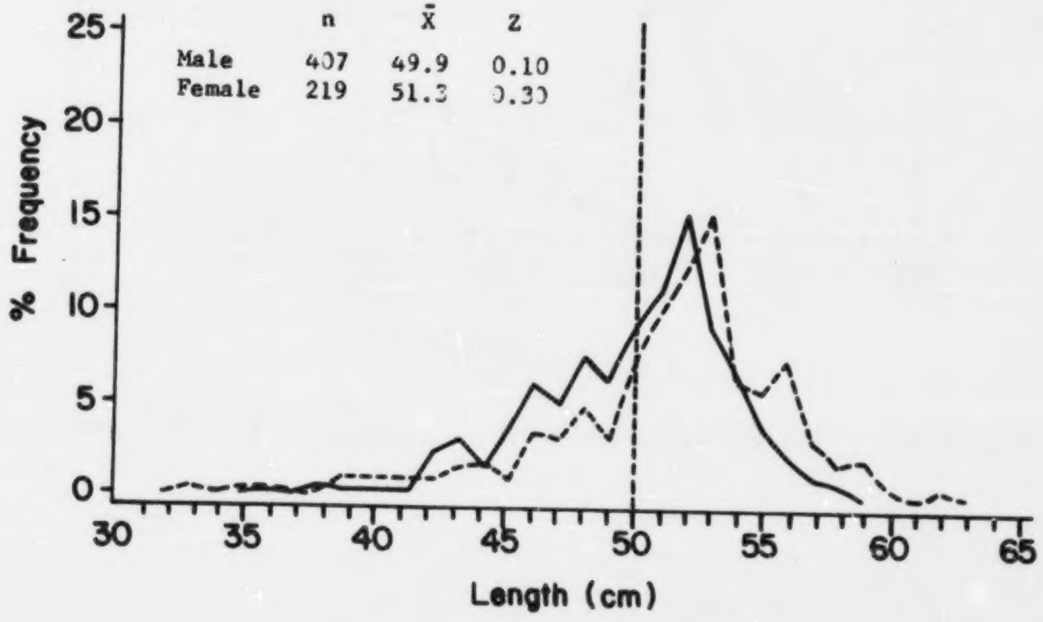


Fig. 9.36. Length distribution of S. pinniger from Kain Island and Quatsino, Area 3D, 1982.

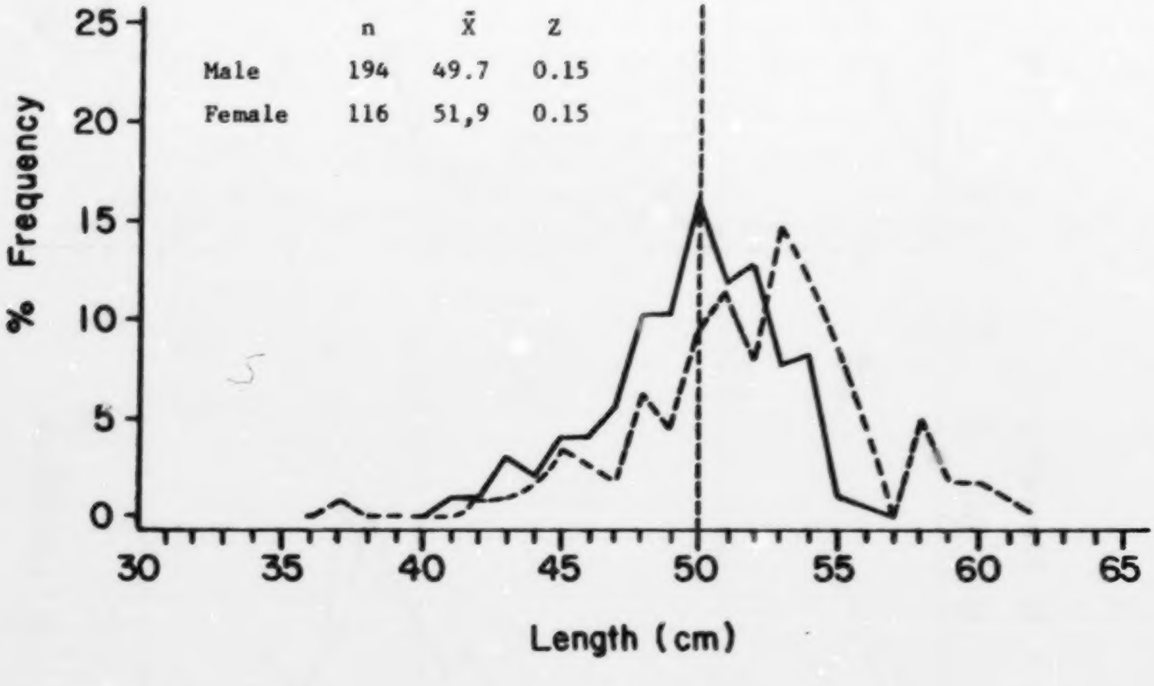


Fig. 9.37. Length distribution of S. pinniger from Nootka, Area 3D, 1983.

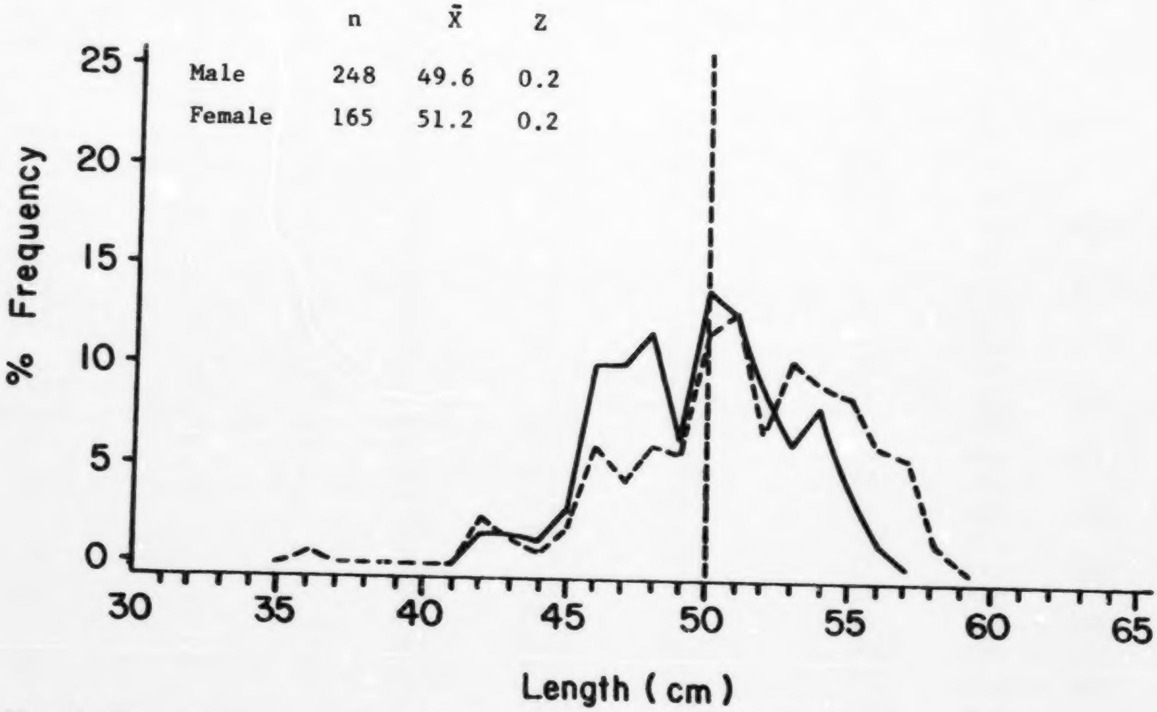


Fig. 9.38. Length composition of S. pinniger from Esperanza, Area 3D, 1984.

Table 9.22. Area 3C landings (t), effort (h), and LPUE (t/h) of *S. flavidus*, 1967-83.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	1	1	22	.06	0	0	-
	USA	25	24	3127	.01	-	-	-
1968	CAN	0	0	0	-	0	0	-
	USA	188	187	1547	.12	-	-	-
1969	CAN	22	22	113	.19	16	55	.29
	USA	465	450	1475	.31	-	-	-
1970	CAN	10	10	360	.03	4	28	1.13
	USA	448	420	1807	.23	-	-	-
1971	CAN	10	10	100	.10	3	16	1.18
	USA	130	120	1184	.10	-	-	-
1972	CAN	11	11	437	.03	0	0	-
	USA	246	240	1278	.19	-	-	-
1973	CAN	20	20	246	.06	2	10	.18
	USA	186	176	1006	.17	-	-	-
1974	CAN	17	17	628	.03	0	0	-
	USA	34	34	817	.04	-	-	-
1975	CAN	6	6	216	.03	0	0	-
	USA	16	16	904	.02	-	-	-
1976	CAN	50	50	931	.05	16	91	.17
	USA	888	888	2395	.37	-	-	-
1977	CAN	237	237	1853	.13	189	83	2.29
	USA	710	710	4390	.16	-	-	-
1978	CAN	45	45	741	.06	18	56	.31
	USA	449	449	5319	.08	-	-	-
1979	CAN	40	40	668	.06	7	23	-.32
	USA	314	314	3606	.09	-	-	-
1980	CAN	37	37	477	.07	3	6	.51
	USA	620	620	2514	.25	-	-	-
1981	CAN	21	21	625	.03	6	17	-.35
	USA	2000	2000	5024	.40	-	-	-
1982	CAN	115	115	837	.14	94	63	1.50
	USA	1447	1447	11819	.12	-	-	-
1983	CAN	16	16	284	.06	10	6	1.48

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

C. Canary rockfish - southern stock

(i) Landing statistics

Catches of S. pinniger by the Canadian fleet have always been low in Area 3C with yield only exceeding 150 t once, in 1981. Canadian trawlers landed 146 t in 1983 with an estimated 3 additional tonnes caught incidental to the hake fishery. Historical landings are shown in Table 9.23. Most of the historical landings originated from the current U.S. zone.

No age composition data is available and length frequency observations are too limited to provide any insight into the size of the stock. Preliminary analyses by U.S. biologists indicate an "Allowable biological landing of 800 t for S. pinniger in the INPFC Vancouver area" (Golden and Demory 1983). This zone includes Area 3C and most of the Washington coast. Their analysis indicates that the current biomass levels are well below those of virgin biomass.

Extensive landings histories of S. pinniger in areas to the north and south and absence of significant landings from 3C, suggest that S. pinniger abundance is limited in Area 3C.

(ii) Recommendations

This stock if immobile probably can probably not sustain a directed fishery, so a conservative yield option would be non-directed fishery. Similarly with S. flavidus, a quota for a directed fishery cannot be considered apart from U.S. management. Negotiation should be begun regarding joint management. In the interim, it is recommended that a ceiling quota of 200 t be applied to the domestic fishery.

Table 9.23. Area 3C landings (t), effort (h), and LPUE (t/h) of *S. pinniger*, 1967-83.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	0	0	0		0	0	-
	USA	226	223	3127	.07	-	-	-
1968	CAN	0	0	0	-	0	0	-
	USA	402	400	1547	.21	0	0	-
1969	CAN	0	0	0		0	0	-
	USA	154	149	1475	.10	-	-	-
1970	CAN	0	0	0	-	0	0	-
	USA	241	225	1807	.09	-	-	-
1971	CAN	51	51	454	.11	40	199	.20
	USA	471	437	1184	.29	-	-	-
1972	CAN	0	0	0		0	0	-
	USA	101	99	1278	.08	-	-	-
1973	CAN	0	0	0		0	0	-
	USA	50	47	1006	.05	-	-	-
1974	CAN	10	10	391	.02	1	6	.18
	USA	29	27	817	.04	-		
1975	CAN	7	7	178	.04	2	2	.90
	USA	205	205	904	.23	-	-	-
1976	CAN	55	55	655	.08	20	66	.30
	USA	208	208	2395	.09	-	-	-
1977	CAN	100	100	1684	.06	19	80	.24
	USA	136	136	4390	.03	-	-	-
1978	CAN	14	14	254	.06	2	9	.22
	USA	202	202	5319	.04	-	-	-
1979	CAN	22	22	477	.05	4	22	.18
	USA	64	64	3606	.02	-	-	-
1980	CAN	18	18	750	.02	9	72	.12
	USA	262	262	2514	.10	-	-	-
1981	CAN	13	13	663	.02	1	7	.14
	USA	188	188	5024	.04	-	-	-
1982	CAN	101	101	1138	.09	78	96	.81
	USA	133	133	11819	.01	-	-	-
1983	CAN	146	146	505	.29	140	214	.65

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).

D. Silvergray, yellowtail, canary rockfishes - Grouped quota for southern stocks.

(i) Recommendations

The combined rockfish yields for conservative, and equilibrium, options are non-directed and 300 t. The equilibrium yield can be increased during the season should the catch by species reflect the desired split.

E. Silvergrey rockfish - northern stock

(i) Landing statistics

Canadian landings of S. brevispinis have only achieved significant levels in the last two years (Table 9.24.). Total U.S. and Canadian landings have averaged 230 t since 1967 and 300 t over the last 10 years. Foreign landings are not considered to have been significant. Recent biological information is limited to one length frequency sample from each of 1982 and 1983 (Fig. 9.31. and Fig. 9.32.). Neither sample has been aged. The 1982 Kain Island sample from the north of 3D indicates relatively old fish with a high proportion of females while the 1983 Nootka sample from the south of 3D is the opposite. This may indicate different exploitation histories and will be monitored to see if it is consistent.

LPUE trend analysis is not possible with the short exploitation history by Canadian boats and the fact we cannot resolve U.S. rockfish effort to species.

(ii) Recommendations

Conservative, equilibrium, and non-sustainable yield options are raised slightly from 1984 levels to 150, 350, and 700 t. The equilibrium level is based on the assumption that the fishery is capable of sustaining a harvest level at least equal to the average over the last 17 years given that there is no evidence to suggest the stock is declining. The 1985 options are slightly higher because the 1984 catch was sufficient to raise the historical mean yield. The non-sustainable level is set at twice the equilibrium yield. S. brevispinis is slow-growing and does not reach full recruitment until at least 20 years of age, so it is presumably vulnerable to exploitation. LPUE and length composition information will be monitored closely and should the stock show symptoms of heavy exploitation, the quota recommendations will be lowered.

Table 9.24. Area 3D landings (t), effort (h), and LPUE (t/h) of *Sebastes brevispinis*, 1967-83.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total Landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	0	0	0	-	-	-	-
	USA	148	148	1344	.11	-	-	-
1968	CAN	0	0	0		-	-	-
	USA	177	172	1381	.12	-	-	-
1969	CAN	0	0	0	-	-	-	-
	USA	328	328	2172	.14	-	-	-
1970	CAN	0	0	0	-	-	-	-
	USA	350	339	2978	.11	-	-	-
1971	CAN	3	3	46	.07	-	-	-
	USA	154	154	1825	.08	-	-	-
1972	CAN	0	0	0	-	-	-	-
	USA	435	435	1691	.26	-	-	-
1973	CAN	0	0	0	-	-	-	-
	USA	226	226	1613	.14	-	-	-
1974	CAN	1	1	12	.08	-	-	-
	USA	227	227	1849	.12	-	-	-
1975	CAN	3	3	9	.33	-	-	-
	USA	75	75	2034	.04	-	-	-
1976	CAN	0	0	0	-	-	-	-
	USA	246	246	1550	.16	-	-	-
1977	CAN	10	10	40	.25	9	23	.39
	USA	52	52	1037	.05	-	-	-
1978	CAN	21	21	236	.09	1	8	.13
	USA	14	14	925	.02	-	-	-
1979	CAN	21	21	109	.19	13	18	.72
	USA	243	243	1206	.20	-	-	-
1980	CAN	20	20	194	.10	7	8	.88
	USA	380	380	1334	.28	-	-	-
1981	CAN	15	15	77	.19	9	24	.38
	USA	136	136	400	.34	-	-	-
1982	CAN	126	126	164	.77	124	126	.99
1983	CAN	562	562	1299	.30	330	745	.44

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

F. Yellowtail rockfish - northern stock

(i) Landing statistics

Catches of S. flavidus in 3D continue to be very low (Table 9.25.). Mean production from North American fisheries is 75 t over the last 17 years and 69 t over the last 10 years. The 1983 landings was 36 t. Significant landings were removed in 1975 and 1976 by Polish vessels, with a rather marked decline in LPUE in the second year of that fishery (Westrheim 1980).

No specific biological data is available, but, as discussed previously, recent tagging work by PBS staff indicates that S. flavidus are relatively mobile. Individuals found in 3D may well be part of the 3C and/or 5A/5B stocks.

(ii) Recommendation

Including the Polish landings generates a mean yield of 600 t over the last 17 years. However, given the marked decline in the second year of that fishery and the relative scarcity based on low domestic yields, the equilibrium yield is probably well below the 600 t level. Guideline yields for conservative, equilibrium and non-sustainable options are unchanged to non-directed, 100 t , and 250 t. Given the incidental nature of this fishery, we recommend that the S. flavidus quota be included as part of the broader rockfish assemblage quota. While the suggested equilibrium yield is 100 t, the low S. flavidus catches in recent years suggest that a combined rockfish quota should assume a S. flavidus contribution of 50 t.

Table 9.25. Area 3D landings (t), effort (h), and LPUE (t/h) of *S. flavidus*, 1967-83.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LUPE
1967	CAN	2	2	4	.50	2	4	.50
	USA	80	80	1344	.06	-	-	-
1968	CAN	0	0	0	-	0	0	-
	USA	25	23	1381	.02	-	-	-
1969	CAN	1	1	27	.04	1	27	.04
	USA	104	99	2172	.05	-	-	-
1970	CAN	1	1	34	.03	1	5	.20
	USA	142	135	2978	.05	-	-	-
1971	CAN	5	5	62	.08	0	0	-
	USA	135	127	1825	.07	-	-	-
1972	CAN	0	0	0	-	0	0	-
	USA	72	72	1691	.04	-	-	-
1973	CAN	0	0	0	-	0	0	-
	USA	23	23	1613	.01	-	-	-
1974	CAN	0	0	0	-	0	0	-
	USA	109	109	1849	.06	-	-	-
1975	CAN	1	1	14	.07	0	0	-
	USA	73	73	2034	.04	-	-	-
1976	CAN	26	25	141	.18	15	43	.35
	USA	4	4	1550	.00	-	-	-
1977	CAN	8	8	50	.16	6	26	.23
	USA	174	174	1037	.17	-	-	-
1978	CAN	37	36	254	.14	15	16	.94
	USA	0	0	925	.00	-	-	-
1979	CAN	8	7	40	.18	3	8	.38
	USA	108	108	1206	.09	-	-	-
1980	CAN	18	18	91	.20	16	53	.30
	USA	45	45	1334	.03	-	-	-
1981	CAN	17	17	66	.26	17	44	.39
	USA	10	10	400	.02	-	-	-
1982	CAN	13	13	96	.13	7	18	.39
1983	CAN	36	31	274	.11	14	24	.58

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

G. Canary rockfish - northern stock

(i) Landing statistics

The landings history of S. pinniger in 3D is shown in Table 9.26. The average annual landing since 1967 is 462 t, over the last 10 years it is 432 t. The Canadian production in 1983 of 707 t represented the highest yield ever for Canadian boats and third highest overall. Ninety-two percent of the landings in 1983 came from Minor Areas 25 and 27 in approximately equal quantities. The suggested equilibrium quota was exceeded by 257 t. Foreign landings were not considered to have been significant.

No recent age composition information is available. Samples collected in 1977 and 1979 indicated a significant proportion of older fish with considerable among-sample variability.

Length composition is summarized in Figures 9.33. to 9.38. These figures were compared with theoretical length frequency curves generated for given Z values. There is no clear distinction between north and south landings. Females appear larger in a combined Esperanza-Nootka sample from the south ($Z = 0.175$) than from more northerly grounds ($Z = 0.20$). Males indicate the opposite, with implied mortality rates of 0.20 in the north and 0.125 in the south.

The implied instantaneous mortality rates based on length frequency observations indicate that, while fishing has had an impact on the stocks, there is no sign of excessive overfishing.

There is little information on relative abundance of the stock. There are no recent or complete biomass surveys and significant production is limited to the most recent 3 years. Qualified LPUE (25%) declined in 1983 but rebounded in 1984 to 0.971 t/hr, equalling the 1982 catch rate.

In the absence of reliable biomass estimates, there is no evidence yet to assume that the fishery cannot sustain the 17-year mean yield of 462 t. Catch rates and length composition information will be monitored closely for any symptoms of increased exploitation.

(ii) Recommendation

We continue to assume that the fishery can sustain the average yield that it has produced in the past. S. pinniger conservative, equilibrium, and non-sustainable yield options for 1984 are raised slightly to 250; 500; and 750 t.

Table 9.26. Area 3D landings (t), effort (h), and LPUE (t/h) of *S. pinniger*, 1967-83.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LUPE
1967	CAN	4	4	41	.10	1	8	.12
	USA	352	352	1344	.26	-	-	-
1968	CAN	19	19	157	.12	10	12	.83
	USA	536	502	1381	.36	-	-	-
1969	CAN	46	46	266	.17	42	127	.33
	USA	625	597	2172	.27	-	-	-
1970	CAN	18	18	96	.19	17	89	.19
	USA	749	713	2978	.24	-	-	-
1971	CAN	15	15	79	.19	12	36	.33
	USA	540	525	1825	.29	-	-	-
1972	CAN	0	0	0	-	0	0	-
	USA	193	193	1691	.11	-	-	-
1973	CAN	0	0	0	-	0	0	-
	USA	443	443	1613	.27	-	-	-
1974	CAN	16	16	70	.23	14	20	.70
	USA	578	578	1849	.31	-	-	-
1975	CAN	7	7	8	.88	7	8	.88
	USA	453	453	2034	.22	-	-	-
1976	CAN	138	138	167	.83	137	141	.97
	USA	187	187	1550	.12	-	-	-
1977	CAN	96	96	124	.77	90	67	1.34
	USA	222	222	1037	.21	-	-	-
1978	CAN	54	54	180	.30	38	47	.81
	USA	861	861	925	.93	-	-	-
1979	CAN	100	92	203	.45	90	153	.59
	USA	251	251	1206	.21	-	-	-
1980	CAN	108	108	308	.35	100	132	.76
	USA	215	215	1334	.16	-	-	-
1981	CAN	53	53	266	.20	41	77	.53
	USA	61	61	400	.15	-	-	-
1982	CAN	215	215	277	.78	208	213	.98
1983	CAN	707	501	1218	.41	453	835	.54

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

H. Silvergray, yellowtail, canary rockfish - Grouped quota for northern stocks

(i) Recommendations

The suggested individual quota options for S. brevispinis and S. pinniger indicate a desired split of 1:1.40. This was almost realized in 1983 with a split of 1:1.25. The situation has changed for the 1984 landings to August 1, wherein the combined landings of 1047 t show a split of 1:2.13. Variances in species ratios were expected when grouped quotas were introduced and the switching of from too little S. brevispinis in 1983 to too much in 1984 landings show how year-to-year variation can cancel out any departures provided the suggested sustainable yields are roughly proportionate to actual landings ratios.

If, however, the grouped quotas are exceeded in a year when the split is less than desirable the individual quotas might actually be exceeded to a great degree. We again recommend use of a grouped quota for 3D shelf rockfish, assuming that landings will not vary significantly from sustainable levels.

If it is suggested that Area 3D be divided again into north and south quotas, consideration should be given to allocating more than 50% to the southern section. In the last 2 years, a greater proportion of the S. brevispinus landings has come from this area and this would assist in keeping the S. brevispinis/S. pinniger ratio closer to 1.40.

The history of U.S. landings suggests that the southern and central portions of Area 3D were exploited more heavily. This is supported by the length composition of S. brevispinis samples but not by those of S. pinniger. We do not recommend managing the two areas separately as we assume that they represent a common recruitment pool.

Suggested combined quotas for the S. brevispinis, S. flavidus, and S. pinniger complex are raised slightly to 250; 750; and 1500 t. Should the species split be close to optional, the overall quota could be raised to match the sum of the individual species options.

9.2.4. Queen Charlotte Sound

A. Silvergray rockfish

(i) Landing statistics

North American landings of S. brevispinis in Areas 5A and 5B have averaged 622 t over the last 17 years, 646 t over the last 10 years (Table 9.27.). The landings in 1983 equalled 642 t. Total Japanese landings in from 1971 to 1977 were estimated to be 607 t which would raise the 17-year average to 682 t.

Age composition information is limited to two samples from 1981. These indicated that a fairly high proportion of older fish still persisted in the population at that time. No clear trends in length composition are apparent. There is a suggestion of declining size in Cape Scott Spit fish since 1977. Size composition of Cape Scott fish sampled in 1982 indicated "Z" values of 0.2 for females and 0.175 for males. *S. brevispinis*, sampled from, the Goose Island grounds continue to be larger, especially those from the northwest Goose Island grounds.

Since 1978, landings and effort have been fairly stable, ranging between 569 and 756 t and 860 and 1538 hours. Qualified LPUE (t/hr) has varied between 0.32 and 0.54 generally without an overall trend, although, the last three years have witnessed a decline from 0.54 in 1981 to 0.33 in 1983. This trend is a source of concern but it is assumed for the present to be within bounds of expected variability.

No biomass surveys have been conducted on this stock.

(ii) Recommendations.

In the absence of any indication that historical landings have significantly reduced the *S. brevispinis* stock in 5A and 5B, we assume that the sustainable yield is at least equal to the historical mean landings. An equilibrium quota of 750 t is suggested for 1985. Should mean size or LPUE continue to decline, quota recommendations will be lowered in the future. Proposed quota options are 400 t for the conservative option; 750 t for the equilibrium option; and 1200 t for the non-sustainable option.

Table 9.27. Area 5A and 5B landings (t), effort (h), and LPUE (t/h) of *S. brevispinis*, 1967-83.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	63	89	539	.17	63	200	.32
	USA	397	396	9,431	.04	-	-	-
1968	CAN	78	78	644	.12	37	109	.34
	USA	933	822	8,488	.10	-	-	-
1969	CAN	78	78	1188	.07	28	152	.18
	USA	1,291	1276	13,557	.09	-	-	-
1970	CAN	14	14	287	.05	6	29	.21
	USA	189	189	9,264	.02	-	-	-
1971	CAN	16	16	331	.05	6	66	.09
	USA	521	512	7,137	.07	-	-	-
1972	CAN	54	54	654	.08	21	108	.19
	USA	251	251	9,224	.03	-	-	-
1973	CAN	40	40	328	.12	33	70	.47
	USA	189	189	9,625	.02	-	-	-
1974	CAN	45	45	412	.11	9	12	.75
	USA	377	377	8,797	.04	-	-	-
1975	CAN	31	31	479	.06	19	61	.31
	USA	306	306	5,179	.06	-	-	-
1976	CAN	172	172	1,914	.09	82	224	.37
	USA	443	443	4,620	.10	-	-	-
1977	CAN	198	198	2,462	.08	123	320	.38
	USA	440	440	5,165	.09	-	-	-
1978	CAN	723	723	4,049	.18	468	1,069	.44
	USA	57	57	909	.06	-	-	-
1979	CAN	629	629	3,885	.16	429	1,225	.35
	USA	298	298	1,696	.18	-	-	-
1980	CAN	631	631	3,279	.19	495	1,538	.32
	USA	147	147	1,146	.13	-	-	-
1981	CAN	569	569	23,471	.24	462	860	.54
	USA	-	-	-	-	-	-	-
1982	CAN	756	735	4,558	.16	521	1,327	.39
1983	CAN	642	537	3,573	.15	365	1,100	.33

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

B. Yellowtail rockfish

(i) Landing statistics

The North American landings history for S. flavidus in Queen Charlotte Sound is shown in Table 9.28. Landings in recent years continue to be well below those of the early 1970s, averaging 365 t from 1980-1983. This is well below the equilibrium yield option of 1500 t.

Little new biological information is available. Age composition in 1980 still indicated a fairly large proportion of older fish in spite of the large annual landings of the 1970s. The only subsequent sample was obtained in 1983. It has not yet been aged but the lengths indicate relatively young males and females.

LPUE remains relatively stable at 0.28-0.42 t/hr and no surveys have been conducted since that of 1978 which indicated a biomass of 16,900 t.

Our assumptions about this resource are unchanged from earlier stock assessment documents (Westrheim 1980; Stocker 1981). Given the low yields since the 1978 biomass survey, we must assume that the fish are still present but less available. As discussed previously, preliminary results from a tagging study indicate that S. flavidus may be wide-ranging and Queen Charlotte Sound fish may be part of an Oregon-Washington-B.C. stock.

(ii) Recommendations

Quota options are unchanged from 1984 at 500 t for a conservative yield; 1500 t for the equilibrium yield; and 2500 t for the non-sustainable yield. The 1983 sample of relatively small fish is a source of some concern but in itself not important enough to alter our perceptions of the stock's status. Owing to the size of the quota and the likelihood of its not being reached, we recommend that the S. flavidus yield be separate from other rockfish.

Table 9.28. Area 5A and 5B landings (t), effort (h), and LPUE (t/h) of *S. flavidus*, 1967-83.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LUPE
1967	CAN	19	19	167	.11	16	24	.67
	USA	998	996	9,431	.11	-	-	-
1968	CAN	23	23	221	.10	18	70	.26
	USA	312	278	8,488	.03	-	-	-
1969	CAN	86	86	604	.14	60	101	.59
	USA	1,913	1,847	13,557	.14	-	-	-
1970	CAN	174	174	714	.24	149	278	.54
	USA	2,634	2,629	9,264	.28	-	-	-
1971	CAN	225	225	980	.23	212	710	.30
	USA	2,049	1,955	7,137	.27	-	-	-
1972	CAN	695	695	2,508	.28	581	1,105	.53
	USA	2,735	2,735	9,224	.30	-	-	-
1973	CAN	521	521	1,403	.37	496	952	.52
	USA	2,753	2,733	9,625	.29	-	-	-
1974	CAN	163	163	1,409	.12	104	284	.37
	USA	809	809	8,797	.09	-	-	-
1975	CAN	414	414	1,885	.22	356	883	.40
	USA	303	303	5,179	.06	-	-	-
1976	CAN	628	628	4,580	.14	429	1381	.31
	USA	363	363	4,620	.08	-	-	-
1977	CAN	1,013	1,011	4,738	.21	862	2,614	.33
	USA	1,242	1,242	5,165	.24	-	-	-
1978	CAN	1,646	1,646	5,050	.33	1,460	2,665	.55
	USA	397	397	909	.44	-	-	-
1979	CAN	1,334	1,321	3,815	.35	1,213	1,778	.68
	USA	192	192	1,696	.11	-	-	-
1980	CAN	471	471	2,631	.18	387	1,100	.35
	USA	81	81	1,146	.07	-	-	-
1981	CAN	285	285	2,281	.12	191	570	.34
1982	CAN	299	278	2,308	.12	197	703	.28
1983	CAN	323	262	1,711	.15	203	448	.45

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

C. Canary rockfish

(i) Landing statistics

Area 5A and 5B landings of S. pinniger are summarized in Table 9.29. Catches over the last 5 years have fluctuated about the 17-year average of 356 t.

No biological material has been aged since 1980, when there appeared to be a reasonable proportion of older fish still present in the population. An examination of length frequency data shows no clear trends although mean female size in samples of 1980-83 is smaller than samples collected in the late 1970s, and smaller than those of 3D. Female length frequencies, when compared with theoretral curves, indicate a high Z value, in excess of 0.3. Male size composition shows no trends and indicates lower Z values.

S. pinniger stocks in British Columbia tend to exhibit a very high "Z" value for females even in presumably unexploited stocks (Archibald et al. 1981). It cannot be assumed, therefore, that a low proportion of older females is indicative of excessive exploitation. If the length frequency samples of S. pinniger reflect the true populations in 5A and 5B, then females do not have a very long reproductive life. Westrheim (1975) reports that 50% maturity was reached at 48 cm for west coast Vancouver Island stocks. This corresponds to an age of 11 years. With a "Z" of 0.3, only 10% remain in the population by age 19. The high apparent "Z" value for females does not necessarily imply that the stock is overfished especially as the males provide contradictory evidence, but it does strongly suggest that S. pinniger must be watched closely to ensure that females can persist in the population long enough to ensure successful reproduction.

No biomass surveys have examined abundance of 5A and 5B S. pinniger. The LPUE times series is very short, limited to 6 years of sizeable Canadian landings. LPUE has fluctuated around a mean of 0.38 t/hr. It is without a clear trend but 1982 and 1983 landings rates were the two lowest of the 6-year series.

(ii) Recommendations

In the absence of definite signs of overfishing it is assumed that S. pinniger in Areas 5A and 5B can sustain a yield equal to the 17-year average landings. However, should qualified LPUE continue to decline and/or the average age of females decrease further, it would be assumed that current yield should be decreased.

Recommended quota options for 1985 are unchanged at a conservative yield of 200 t; and equilibrium yield of 500 t; and a non-sustainable yield of 1000 t.

Table 9.29. Area 5A and 5B landings (t), effort (h), and LPUE (t/h) of *S. pinniger*, 1967-83.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LUPE
1967	CAN	41	41	535	.08	13	32	.41
	USA	216	215	9,431	.02			
1968	CAN	49	49	576	.09	31	78	.40
	USA	1,034	937	8,488	.11			
1969	CAN	67	67	733	.09	37	110	.34
	USA	464	418	13,557	.03			
1970	CAN	6	6	80	.08	4	12	.33
	USA	220	220	9,264	.02			
1971	CAN	18	18	329	.05	6	8	.75
	USA	207	183	7,137	.03			
1972	CAN	0	0	0	-	0	0	-
	USA	61	61	9,224	.01			
1973	CAN	29	29	119	.24	23	80	.29
	USA	298	298	9,625	.03			
1974	CAN	3	3	81	.04	1	7	.14
	USA	257	257	8,797	.03			
1975	CAN	23	23	403	.06	15	17	.88
	USA	189	189	5,179	.04			
1976	CAN	92	92	1,558	.06	16	49	.33
	USA	447	447	4,620	.10			
1977	CAN	121	121	2,356	.05	53	192	.28
	USA	288	288	5,165	.06			
1978	CAN	263	263	2,692	.10	101	242	.42
	USA	8	8	909	.01			
1979	CAN	308	308	3,070	.10	211	582	.36
	USA	62	62	1,696	.04			
1980	CAN	281	281	2,199	.13	198	451	.44
	USA	88	88	1,146	.08			
1981	CAN	185	185	1778	.10	86	206	.42
1982	CAN	359	331	3,223	.10	210	706	.30
1983	CAN	360	315	2,939	.11	163	466	.35

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

D. Silvergray, canary rockfish - Grouped quota

(i) Recommendations

The equilibrium yields for *S. brevispinis* and *S. pinniger* in Areas 5A and 5B are 750 and 500 t for a total of 1250 t. Over the last five years the *S. brevispinis* production has averaged 70% of the two species'combined yield. A 1250 t quota would therefore be expected to result in yields of 875 t of *S. brevispinis* and 375 t of *S. pinniger*. As the *S. brevispinis* landings would then be exceeding the sustainable level, we recommend a combined quota of 1100 t which can be raised to 1250 t should the proportion of *S. brevispinis* not significantly exceed 60%. The conservative and non-sustainable grouped options are suggested to be 500 and 2000 t.

9.2.5. Hecate Strait

A. Silvergray rockfish

(i) Landing statistics

Production from the *S. brevispinis* fishery in Areas 5C and 5D is summarized in Table 9.30. Catches became significant in 1977 and have since fluctuated about a mean of 277 t. Yield in 1983 was 333 t.

There is no recent ageing information. Samples from 1980 indicated that a fair proportion of older fish were present in the population at that time.

A length frequency sample from Cape St. James (Area 5C) 1983 indicates very small females in low numbers (x = 48.5, n = 40) and smaller than average males (x = 50, n = 260). These correspond to theoretical Z values of >0.3 for the females and 0.15 to 0.20 for the males. A sample collected from the Horseshoe ground also indicated a very low proportion of females (5%) of very small size (x = 49.6 cm). The males are larger than those of Cape St. James (x = 51.5, n = 284) with the composition corresponding to a Z of 0.10 from the theoretical length frequency curves. The Horseshoe sample is approximately equal to a sample collected in 1980. The 1983 Cape St. James fish are somewhat smaller than a 1979 sample. This could represent a fishing-down effect or, conversely, be a sign of large incoming year-classes.

Qualified (25%) LPUE has tended to increase over the seven years of the fishery, being highest in 1981 (.86 t/hr) and 1983 (.80 t/hr). No surveys have been conducted on this stock.

The fishery has too short a history and there is too little biological data to reach any conclusions about the status of this stock. The rising LPUE probably indicates the learning response of the fishermen and not an increasing stock size but there is certainly nothing in the LPUE to indicate a declining stock.

(ii) Recommendations

There is no firm indication that the stock is being over-harvested so quotas are unchanged from those recommended for 1984: a conservative yield of 300 t; an equilibrium yield of 600 t; and a non-sustainable yield of 1000 t. Landings from 5D are low enough that this quota could be applied to the two areas if it would simplify management.

B. Yellowtail, canary rockfish - Grouped quota

(i) Landing statistics

Fisheries for S. flavidus and S. pinniger, in Areas 5C and 5D, continue to be inconsequential in recent years. Qualified (25%) landings in 1983 equalled 36 and 38 t respectively. In the absence of significant fisheries, no new information has become available since the last published stock assessments.

(ii) Recommendation

Recommended yield options are shown below:

	5C			5D		
S. flavidus	100	200	400	150	350	500
S. pinniger	150	250	500	n.d.	100	200
Combined	200	400	800	150	400	600

These are suggested as guidelines only. Should they be reached, then consideration could be given to raising the quotas based on size composition, species proportions and the progress of other fisheries. The two areas combined if it would ease management, yields would be the sum of the area yields shown, but in that case the two species should be separate.

9.2.6. West Coast of Queen Charlotte Islands

A. Silvergray, yellowtail, canary rockfishes - Grouped quota

(i) Recommendations

Shelf rockfish fisheries remain inconsequential with no new information being obtained since earlier stock assessment documents.

Yield options are suggested as guidelines only and are unchanged from those of 1984. Guideline combined yields for S. brevispinis, S. flavidus, and S. pinniger are 200 t for 5E North and 950 t for 5E South. There is not sufficient background information to suggest conservative or non-sustainable yields.

Table 9.30. Area 5C and 5D landings (t), effort (h), and LPUE (t/h) of *S. brevispinis*, 1971-83.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings	Landings	Effort	LPUE	Landings	Effort	LPUE
1971	CAN	34	34	229	.15	24	121	.20
1972	CAN	61	61	232	.26	44	54	.81
1973	CAN	10	10	147	.07	-	-	-
1974	CAN	13	13	64	.20	11	34	.33
1975	CAN	11	11	191	.06	4	5	.79
1976	CAN	121	121	1,429	.08	55	414	.13
1977	CAN	234	234	2,059	.11	142	468	.30
1978	CAN	232	232	1392	.17	177	301	.59
1979	CAN	380	375	2,881	.13	189	473	.40
1980	CAN	337	337	1,886	.18	235	381	.62
1981	CAN	304	263	1,610	.16	221	258	.86
1982	CAN	121	100	1,339	.08	59	94	.63
1983	CAN	333	288	883	.33	247	310	.80

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